Stage 1 Technical Assessment as of February 2000 Water Resource Inventory Area 17

Prepared for

Water Resource Inventory Area 17 Planning Unit

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October 2000

Project No. 553-1820-007

TABLE OF CONTENTS

1. INTRODUCTION AND STUDY AREA DESCRIPTION 1-1

1.1 STAGE 1 TECHNICAL ASSESSMENT PURPOSE AND SCOPE 1-1

1.2 FUTURE WORK 1-2

1.3 WRIA 17 STUDY AREA GENERAL DESCRIPTION 1-2

1.4 SUMMARY OF LAND USE VARIATIONS AND GROWTH PROJECTIONS 1-2

1.4.1 Summary of Land Use in WRIA 17 1-2

1.4.2 Summary of Population and Potential Growth in WRIA 17 1-4

2. PRECIPITATION ANALYSIS 2-1

2.1 EXISTING PRECIPITATION DATA 2-1

2.1.1 Western Regional Climate Center 2-1

2.1.2 Natural Resources Conservation Service 2-1

2.1.3 Other Data Sources 2-1

2.2 SPATIAL DISTRIBUTION OF PRECIPITATION 2-2

2.3 VARIATIONS AND TRENDS IN PRECIPITATION OVER TIME 2-2

3. WATER QUALITY 3-1

3.1 SURFACE WATER QUALITY 3-1

3.1.1 Scope and Objectives 3-1

3.1.2 Water Body Classifications 3-1

3.1.3 State of Washington Water Quality Standards 3-1

3.1.4 Shellfish Harvesting Standards 3-4

3.1.5 Summary of WRIA 17 Surface Water Quality 3-5

3.1.6 POTENTIAL SURFACE WATER POLLUTANT SOURCES 3-6

3.1.7 Surface Water Quality Data Quality And Quantity 3-6

3.2 GROUNDWATER QUALITY 3-7

3.2.1 Chloride 3-9

3.2.2 Nitrate 3-11

3.2.3 Iron and Manganese 3-13

3.2.4 Confirmed and/or Suspected Groundwater Contamination Sites 3-14

3.2.5 Sub-Basin Groundwater Quality 3-14

4. WATER QUANTITY 4-1

4.1 WATER QUANTITY IN WRIA 17 4-1

4.1.1 Groundwater Quantity and Recharge 4-1

4.1.2 Surface Water Quantity 4-16

4.2 WATER ALLOCATIONS AND USE IN WRIA 17 4-17

4.2.1 Data Sources and Data Reduction 4-19

4.2.2 Groundwater Allocations 4-21

4.2.3 Groundwater Allocation and Use 4-25

4.2.4 Surface Water Allocation and Use 4-32

4.3 PRELIMINARY WATER BUDGET 4-34

TABLE OF CONTENTS (Continued)

4.3.1 Preliminary Water Budget Components 4-36
4.3.2 Simplified Water Budget 4-37
4.3.3 Comparing Groundwater Quantity with Use 4-38
4.3.4 Comparing Surface Water Quantity to Use 4-41
4.4 HYDRAULIC CONTINUITY POTENTIAL....4-41
4.4.1 Relative Hydraulic Continuity Assessment Methodology 4-42
4.4.2 Overview of Relative Hydraulic Continuity in WRIA 17....4-44
4.5 EFFECTS OF LAND USE VARIATION ON WATER QUANTITY....4-45
4.5.1 Potential Land Use Effects on Groundwater Quantity....4-45
4.5.2 EFFECTS OF LAND USE ON SURFACE WATER QUANTITY....4-50
4.6 SUMMARY OF PROJECTED IMPACTS OF GROWTH ON WATER DEMAND....4-50
4.7 CONSERVATION OPTIONS....4-51
4.7.1 Tiered Water Rate Structures....4-51
4.7.2 Modification of Landscape Irrigation Practices....4-51
4.7.3 Water Conservation in Water Supply Systems and Individual Homes....4-51
4.7.4 Educational Programs 4-53
4.7.5 Water Re-Use....4-53
4.7.6 Increased Storage, Either Through Surface Storage or Aquifer Storage 4-53
4.7.7 Water Conservancy Boards To Facilitate Water Rights Transfers 4-54
4.7.8 Improve Water Measurement Network....4-54
4.7.9 Implement Water Conservation At Port Townsend Paper Company....4-54

5. HABITAT AND STOCK ASSESSMENT 5-1
5.1 PURPOSE AND SCOPE 5-1
5.2 HABITAT DATA CONSIDERATIONS....5-1
5.3 OVERVIEW OF SALMONID STOCKS IN WRIA 17 5-2
5.4 SPECIES ACCOUNTS....5-3
5.4.1 Summer Chum Salmon 5-3
5.4.2 Fall Chum Salmon 5-8
5.4.3 Coho Salmon....5-9
5.4.4 Chinook Salmon....5-11
5.4.5 Steelhead 5-11
5.4.6 Coastal Cutthroat Trout....5-13
5.4.7 Bull Trout....5-13
5.5 HABITAT ASSESSMENT APPROACH AND METHODOLOGIES....5-13
5.5.1 Habitat Requirements of Salmonids Found in WRIA 17....5-13
5.5.2 Assessment Methodologies....5-14
5.5.3 Limiting Factor Analyses....5-16
5.6 EVALUATION OF HABITAT DATA QUALITY 5-17
5.7 SUMMARY OF HABITAT QUALITY....5-19
5.8 INVENTORY OF BARRIERS TO FISH MIGRATION 5-26
5.9 SUMMARY OF PROJECTED IMPACTS OF GROWTH AND HUMAN IMPACTS ON HABITAT 5-28

TABLE OF CONTENTS (Continued)

5.10 FISHERIES MANAGEMENT 5-30
5.11 CURRENT COMMERCIAL AND RECREATIONAL FISHERIES 5-30
5.12 HARVEST OBJECTIVES 5-32

6. INSTREAM FLOW 6-1
6.1 INTRODUCTION 6-1
6.1.1 Instream Flows and Current Administrative Status 6-1
6.1.2 Definitions 6-1
6.2 OPTIMUM INSTREAM FLOWS AND STUDY RESULTS 6-2
6.3 EXISTING STREAM FLOW RECOMMENDATIONS 6-10
6.4 RECOMMENDED AND DIRECTIONS IN REGULATORY ACTION/INTENT 6-10
6.5 EXTENT WHICH CURRENT FLOW REGIMES MEET EXISTING INSTREAM FLOW REQUIREMENTS 6-10
6.6 ASSESSMENT OF DATA QUALITY AND QUANTITY 6-11
6.6.1 Data Quality 6-11
6.6.2 Data Quantity 6-11

7. DATA QUALITY, GAPS AND LIMITATIONS 7-1
7.1 NATURE AND OVERVIEW OF DATA GAPS 7-1
7.2 WATER QUALITY 7-1
7.2.1 Surface Water Quality 7-1
7.2.2 Groundwater Quality 7-2
7.3 WATER QUANTITY 7-4
7.3.1 Hydrogeology 7-4
7.3.2 Hydrology and Surface Water Quantity 7-5
7.3.3 Water Allocation and Use 7-5
7.4 FISHERIES RESOURCES AND HABITAT QUALITY 7-6
7.5 INSTREAM FLOW 7-6
7.6 GENERAL LAND-USE AND PLANNING DATA 7-7

8. BIG QULICENE SUB-BASIN 8-1
8.1 SUB-BASIN DESCRIPTION 8-1
8.1.1 Surface Water Features 8-1
8.1.2 Groundwater Features 8-3
8.1.3 Land Use 8-3
8.2 WATER QUALITY 8-4
8.2.1 Surface Water Quality 8-4
8.2.2 Marine Water 8-6
8.2.3 Inventory of Potential Surface Water Contaminant Sources 8-6
8.2.4 Summary of Surface Water Trends and Compliance Problems 8-8
8.2.5 Groundwater Quality 8-9
8.3 WATER QUANTITY 8-9
8.3.1 Groundwater Quantity 8-9

TABLE OF CONTENTS (Continued)

8.3.2 Surface Water Quantity 8-9
8.3.3 Estimate of Water Use and Allocation 8-11
8.3.4 Hydraulic Continuity Potential 8-15
8.4 FISHERIES AND FISH HABITAT 8-15
8.4.1 Salmonid Stocks 8-15
8.4.2 Habitat Assessment 8-21
8.4.3 Historic Habitat Conditions 8-24
8.4.4 Limiting Factors for Chum Salmon 8-25
8.4.5 Restoration Activities 8-26
8.5 INSTREAM FLOW 8-27
8.6 FUTURE GROWTH AND POTENTIAL IMPACTS 8-28
8.6.1 Big Quilcene Sub-basin Population Growth 8-28
8.6.2 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity 8-28
8.6.3 Potential Impacts of Growth in the Big Quilcene Sub-basin on Water Demand 8-29
8.6.4 Potential Impacts of Growth on Habitat 8-29
8.6.5 Conservation Options 8-29
8.7 DATA SYNTHESIS AND INTEGRATION 8-30
8.8 DATA QUALITY, DATA GAPS AND LIMITATIONS 8-30
8.8.1 Water Quality 8-30
8.8.2 Water Quantity 8-31
8.8.3 Habitat 8-31
8.8.4 In-Stream Flow 8-31

9. LITTLE QUILCENE SUB-BASIN 9-1
9.1 SUB-BASIN DESCRIPTION 9-1
9.1.1 Surface Water Features 9-1
9.1.2 Groundwater Features 9-1
9.1.3 Land Use 9-3
9.2 WATER QUALITY 9-3
9.2.1 Surface Water Quality 9-3
9.2.2 Marine Water Quality 9-10
9.2.3 Inventory of Potential Surface Water Contaminant Sources 9-10
9.2.4 Summary of Surface Water Trends and Compliance Problems 9-11
9.2.5 Groundwater Quality 9-11
9.3 WATER QUANTITY 9-11
9.3.1 Groundwater Quantity 9-11
9.3.2 Surface Water Quantity 9-12
9.3.3 Estimate of Water Use and Allocation 9-12
9.3.4 Hydraulic Continuity Potential 9-16
9.4 HABITAT 9-17
9.4.1 Salmonid Stocks 9-17

TABLE OF CONTENTS (Continued)

9.4.2 Habitat Assessment 9-20
9.4.3 RESTORATION ACTIVITIES 9-24
9.5 INSTREAM FLOW 9-24
9.6 FUTURE GROWTH AND POTENTIAL IMPACTS 9-25
9.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity 9-25
9.6.2 Population Growth 9-25
9.6.3 Potential Impacts of Growth on Water Demand 9-25
9.6.4 Potential Impacts of Growth on Habitat 9-26
9.6.5 Conservation Options 9-26
9.7 DATA SYNTHESIS AND INTEGRATION 9-27
9.8 DATA QUALITY, DATA GAPS AND LIMITATIONS 9-27
9.8.1 Water Quality 9-27
9.8.2 Water Quantity 9-27
9.8.3 Habitat 9-28
9.8.4 In-stream Flow 9-28

10. DABOB – THORNDYKE SUB-BASIN 10-1
10.1 SUB-BASIN DESCRIPTION 10-1
10.1.1 Surface Water Features 10-1
10.1.2 Groundwater Features 10-1
10.1.3 Land Use 10-3
10.2 WATER QUALITY 10-3
10.2.1 Surface Water Quality 10-3
10.2.2 Marine Water Quality 10-5
10.2.3 Inventory of Potential Surface Water Contaminant Sources 10-5
10.2.4 Summary of Surface Water Trends and Compliance Problems 10-6
10.2.5 Groundwater Quality 10-6
10.3 WATER QUANTITY 10-7
10.3.1 Groundwater Quantity 10-7
10.3.2 Surface Water Quantity 10-7
10.3.3 Estimate of Water Use and Allocation 10-7
10.4 HYDRAULIC CONTINUITY POTENTIAL 10-8
10.5 HABITAT 10-10
10.5.1 Salmonid Species Present 10-10
10.5.2 Habitat 10-10
10.5.3 Restoration Activities 10-12
10.6 INSTREAM FLOW 10-13
10.7 FUTURE PROJECTIONS AND POTENTIAL IMPACTS 10-13
10.7.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity 10-13
10.7.2 Population Growth 10-13
10.7.3 Conservation Options 10-15

TABLE OF CONTENTS (Continued)

10.8 DATA SYNTHESIS AND INTEGRATION 10-15
10.9 DATA QUALITY, DATA GAPS AND LIMITATIONS 10-15
10.9.1 Water Quality 10-15
10.9.2 Water Quantity 10-16
10.9.3 Habitat 10-16
10.9.4 In-Stream Flow 10-16

11. LUDLOW SUB-BASIN 11-1
11.1 SUB-BASIN DESCRIPTION 11-1
11.1.1 Surface Water Features 11-1
11.1.2 Groundwater Features 11-1
11.1.3 Land Use 11-3
11.2 WATER QUALITY 11-3
11.2.1 Surface Water Quality 11-3
11.2.2 Marine Water 11-5
11.2.3 Inventory of Potential Surface Water Contaminant Sources 11-6
11.2.4 Summary of Surface Water Trends and Compliance Problems 11-7
11.2.5 Groundwater Quality 11-7
11.3 WATER QUANTITY 11-8
11.3.1 Groundwater Quantity 11-8
11.3.2 Surface Water Quantity 11-8
11.3.3 Estimate of Water Use and Allocation 11-8
11.3.4 Hydraulic Continuity Potential 11-10
11.4 HABITAT 11-11
11.4.1 Salmonid Species Present 11-11
11.4.2 Habitat Assessment 11-11
11.4.3 Restoration Activities 11-12
11.5 INSTREAM FLOW 11-12
11.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS 11-12
11.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity 11-12
11.6.2 Sub-basin Population Growth 11-13
11.6.3 Potential Impacts of Growth on Water Demand 11-13
11.6.4 Potential Impacts of Growth on Habitat 11-13
11.6.5 Conservation Options for the Ludlow Sub-Basin 11-14
11.7 DATA SYNTHESIS AND INTEGRATION 11-14
11.8 DATA QUALITY, DATA GAPS AND LIMITATIONS 11-15
11.8.1 Water Quality 11-15
11.8.2 Water Quantity 11-15
11.8.3 Habitat 11-15
11.8.4 Instream Flow 11-16

12. CHIMACUM SUB-BASIN 12-1

TABLE OF CONTENTS (Continued)

12.1 SUB-BASIN DESCRIPTION 12-1
12.1.1 Surface Water Features 12-1
12.1.2 Groundwater Features 12-3
12.1.3 Land Use 12-3
12.2 WATER QUALITY 12-4
12.2.1 Surface Water Quality 12-4
12.2.2 Marine Water Quality 12-17
12.2.3 Inventory of Potential Surface Water Contaminant Sources 12-17
12.2.4 Groundwater Quality 12-18
12.3 WATER QUANTITY 12-18
12.3.1 Groundwater Quantity 12-18
12.3.2 Surface Water Quantity 12-18
12.3.3 Estimate of Water Use and Allocation 12-19
12.3.4 Hydraulic Continuity Potential 12-24
12.4 HABITAT 12-25
12.4.1 Salmonid Distribution 12-25
12.4.2 Habitat Assessment 12-28
12.4.3 Limiting Factors for Summer Chum Salmon 12-29
12.4.4 Restoration Projects 12-30
12.5 INSTREAM FLOW 12-32
12.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS 12-32
12.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity 12-32
12.6.2 Sub-basin Population Growth 12-33
12.6.3 Potential Impacts of Growth on Water Demand 12-33
12.6.4 Potential Impacts of Land-Use and Growth on Habitat 12-33
12.6.5 Conservation Options 12-34
12.7 DATA SYNTHESIS AND INTEGRATION 12-34
12.8 DATA QUALITY, GAPS AND LIMITATIONS 12-35
12.8.1 Water Quality 12-35
12.8.2 Water Quantity 12-35
12.8.3 Habitat 12-36
12.8.4 Instream Flow 12-36

13. SALMON – SNOW SUB-BASIN 13-1
13.1 SUB-BASIN DESCRIPTION 13-1
13.1.1 Surface Water Features 13-1
13.1.2 Groundwater Features 13-3
13.1.3 Land Use 13-3
13.2 WATER QUALITY 13-4
13.2.1 Surface Water Quality 13-4
13.2.2 Marine Water Quality 13-8
13.2.3 Inventory of Potential Surface Water Contaminant Sources 13-9

TABLE OF CONTENTS (Continued)

13.2.4 Summary of Surface Water Trends and Compliance Problems 13-10
13.2.5 Groundwater Quality 13-10
13.3 WATER QUANTITY 13-10
13.3.1 Groundwater Quantity 13-10
13.3.2 Surface Water Quantity 13-11
13.3.3 Estimate of Water Quantity and Allocation 13-11
13.3.4 Hydraulic Continuity Potential 13-15
13.4 HABITAT 13-15
13.4.1 Salmonid Species Distribution 13-15
13.4.2 Salmon Creek Habitat Assessment 13-20
13.4.3 Snow Creek Habitat Assessment 13-21
13.4.4 Limiting Factors for Salmon Creek Summer Chum Salmon 13-22
13.4.5 Limiting Factors for Snow Creek Summer Chum Salmon 13-22
13.4.6 Salmon-Snow Watershed Analysis 13-23
13.4.7 Restoration Activities 13-23
13.5 INSTREAM FLOW 13-24
13.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS 13-24
13.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity 13-24
13.6.2 Sub-basin Population Growth 13-25
13.6.3 Potential Impacts of Growth on Water Demand 13-25
13.6.4 Potential Impacts of Growth and Land-Use on Habitat 13-25
13.6.5 Conservation Options for the Salmon-Snow Sub-basin 13-25
13.7 DATA SYNTHESIS AND INTEGRATION 13-26
13.8 DATA QUALITY, GAPS AND LIMITATIONS 13-26
13.8.1 Water Quality 13-26
13.8.2 Water Quantity 13-26
13.8.3 Habitat 13-27
13.8.4 Instream Flow 13-27

14. WEST SEQUIM BAY SUB-BASIN 14-1
14.1 BASIN DESCRIPTION 14-1
14.1.1 Surface Water Features 14-1
14.1.2 Groundwater Features 14-3
14.1.3 Land Use 14-3
14.2 WATER QUALITY 14-4
14.2.1 Surface Water Quality 14-4
14.2.2 Marine Water Quality 14-4
14.2.3 Inventory of Potential Surface Water Contaminant Sources 14-4
14.2.4 Summary of Trends and Compliance Problems 14-5
14.2.5 Groundwater Quality 14-5
14.3 WATER QUANTITY 14-5
14.3.1 Groundwater Quantity 14-5

TABLE OF CONTENTS (Continued)

14.3.2 Surface Water Quantity 14-6
14.3.3 Estimate of Water Use and Allocation 14-6
14.3.4 Hydraulic Continuity Potential 14-8
14.4 HABITAT 14-8
14.4.1 Salmonid Distribution And Stock Assessment 14-8
14.4.2 Jimmycomelately Creek Habitat Assessment 14-10
14.4.3 Restoration Activities 14-12
14.5 INSTREAM FLOW 14-12
14.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS 14-13
14.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity 14-13
14.6.2 Population Growth 14-13
14.6.3 Potential Impacts of Growth on Water Demand 14-13
14.6.4 Potential Impacts of Land Use and Growth on Habitat 14-13
14.6.5 Conservation Options 14-14
14.7 DATA SYNTHESIS AND INTEGRATION 14-14
14.8 DATA QUALITY, GAPS AND LIMITATIONS 14-14
14.8.1 Water Quality 14-14
14.8.2 Water Quantity 14-14
14.8.3 Habitat 14-15
14.8.4 In-stream Flow 14-15

15. MILLER SUB-BASIN 15-1
15.1 SUB-BASIN DESCRIPTION 15-1
15.1.1 Surface Water Features 15-1
15.1.2 Groundwater Features 15-1
15.1.3 Land Use 15-3
15.2 WATER QUALITY 15-3
15.2.1 Surface Water Quality 15-3
15.2.2 Marine Water Quality 15-3
15.2.3 Inventory of Potential Surface Water Contaminant Sources 15-4
15.2.4 Summary of Surface Water Trends and Compliance Problems 15-4
15.2.5 Groundwater Quality 15-4
15.3 WATER QUANTITY 15-5
15.3.1 Estimate of Water Quantity 15-5
15.3.2 Surface Water Quantity 15-5
15.3.3 Estimate of Water Use and Allocation 15-5
15.3.4 Hydraulic Continuity Potential 15-8
15.4 HABITAT 15-8
15.5 INSTREAM FLOW 15-8
15.6 FUTURE PROJECTION AND POTENTIAL IMPACTS 15-8
15.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity 15-8

TABLE OF CONTENTS (Continued)

15.6.2 Population Growth 15-8
15.6.3 Potential Impacts of Land Use and Growth on Habitat 15-8
15.6.4 Potential Impacts of Growth on Water Demand 15-9
15.6.5 Conservation Options 15-9
15.7 DATA SYNTHESIS AND INTEGRATION 15-9
15.8 DATA QUALITY, GAPS AND LIMITATIONS 15-9
15.8.1 Water Quality 15-10
15.8.2 Water Quantity 15-10
15.8.3 Habitat 15-10
15.8.4 In-stream Flow 15-10

16. QUIMPER SUB-BASIN 16-1
16.1 BASIN DESCRIPTION 16-1
16.1.1 Surface Water Features 16-1
16.1.2 Groundwater Features 16-1
16.1.3 Land Use 16-1
16.2 WATER QUALITY 16-1
16.2.1 Surface Water Quality 16-1
16.2.2 Marine Water Quality 16-3
16.2.3 Inventory of Potential Surface Water Contaminant Sources 16-3
16.2.4 Summary of Surface Water Trends and Compliance Problems 16-4
16.2.5 Groundwater Quality 16-5
16.3 WATER QUANTITY 16-5
16.3.1 Groundwater Quantity 16-5
16.3.2 Surface Water Quantity 16-5
16.3.3 Estimated Water Use and Allocation 16-5
16.3.4 Hydraulic Continuity Potential 16-6
16.4 HABITAT 16-8
16.5 INSTREAM FLOW 16-8
16.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS 16-8
16.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity 16-8
16.6.2 Population Growth 16-8
16.6.3 Potential Impacts of Land Use and Growth on Habitat 16-8
16.6.4 Potential Impacts of Growth on Water Demand 16-9
16.6.5 Conservation Options 16-9
16.7 DATA SYNTHESIS AND INTEGRATION 16-9
16.8 DATA QUALITY, GAPS AND LIMITATIONS 16-10
16.8.1 Water Quality 16-10
16.8.2 Water Quantity 16-10
16.8.3 Habitat 16-10
16.8.4 In-stream Flow 16-10

TABLE OF CONTENTS (Continued)

17. INDIAN – MARROWSTONE SUB-BASIN 17-1

17.1 BASIN DESCRIPTION 17-1
- 17.1.1 Surface Water Features 17-1
- 17.1.2 Groundwater Features 17-1
- 17.1.3 Land Use 17-1

17.2 WATER QUALITY 17-3
- 17.2.1 Surface Water Quality 17-3
- 17.2.2 Marine Water Quality 17-3
- 17.2.3 Inventory of Potential Surface Water Contaminant Sources 17-4
- 17.2.4 Summary of Surface Water Trends and Compliance Problems 17-4
- 17.2.5 Groundwater Quality 17-4

17.3 WATER QUANTITY 17-5
- 17.3.1 Groundwater Use and Allocation 17-5
- 17.3.2 Surface Water Use and Allocation 17-6
- 17.3.3 Hydraulic Continuity Potential 17-6

17.4 HABITAT 17-6

17.5 INSTREAM FLOW 17-6

17.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS 17-8
- 17.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity 17-8
- 17.6.2 Population Growth 17-8
- 17.6.3 Potential Impacts of Growth on Water Demand 17-8
- 17.6.4 Potential Impacts of Land Use and Growth on Habitat 17-8
- 17.6.5 Conservation Options for the Indian-Marrowstone Sub-basin 17-9

17.7 DATA SYNTHESIS AND INTEGRATION 17-9

17.8 DATA QUALITY, GAPS AND LIMITATIONS 17-9
- 17.8.1 Water Quality 17-9
- 17.8.2 Water Quantity 17-9
- 17.8.3 Habitat 17-10
- 17.8.4 In-stream Flow 17-10

18. REFERENCES 18-1

TABLE OF CONTENTS (Continued)

APPENDICES

A GIS EXHIBITS

1 Zoning
2 Climatological and Stream Gaging Stations and Precipitation Distribution
3 Surface Water Quality Assessment
4 Chloride Concentrations
5 Nitrate-Nitrogen Concentrations
6 Estimated Recharge in Inches/Year
7 Estimated Rejected Recharge (Runoff) in Inches/Year
8 Groundwater Rights – Qa in AF/YR, Consumptive Use Only
9 Groundwater Applications – Qi in GPM, Consumptive Use Only
10 Count of Groundwater Claims per Section, Consumptive Use Only
11 Estimated Annual Groundwater Use per Section
12 Surface Water Rights – Qi in CFS, Consumptive Use Only
13 Surface Water Rights – Qa in AF/YR, Consumptive Use Only
14 Surface Water Claims – Qi in CFS, Consumptive Use Only
15 Surface Water Claims – Qa in AF/YR, Consumptive Use Only
16 Surface Water Applications – Qi in CFS, Consumptive Use Only
17 Generalized Surficial Geology and Relative Hydraulic Continuity Potential
18 Habitat Assessment

B MISCELLANEOUS STREAM FLOW DATA

LIST OF FIGURES

ES-1 WRIA 17 Project Area and Sub-basins xxi
ES-2 WRIA 17 Stage 1 Assessment, Summary of Concurrent Issues xxxv
1-1 WRIA 17 Location and Vicinity 1-3
2-1 Monthly Average Precipitation, Port Townsend Period of Record 1948-1999 2-4
2-2 Monthly Average Precipitation, Chimacum Period of Record 1948-1999 2-5
2-3 Monthly Average Precipitation from the Quilcene 2 SW Gage Period of Record 1948-1999 2-6
2-4 Monthly Average Precipitation, Mt Crag Period of Record 1990-1999 2-7
2-5 Precipitation Expressed as Monthly Percentage of Annual Total 2-8
2-6 Exceedance Values: Port Townsend Precipitation Period of Record 1948-1999 2-9
2-7 Exceedance Values: Chimicum Precipitation Period of Record 1948-1999 2-10
2-8 Exceedance Values: Quilcene 2SW Gage Precipitation Period of Record 1948-1999 2-11
2-9 Exceedance Values: Mt Crag Precipitation Period of Record 1990-1999 2-12
2-10 Trends in Annual Precipitation: 5-Year Moving Average 2-13
3-1 Comparison of Chlorine and Nitrate Concentration as a Function of Well Depth 3-12
4-1 Modeled Runoff as a Function of Precipitation 4-12
4-2 Recharge Trends through Outwash and Till 4-13
4-3 Estimated Recharge for Till and Outwash 4-15
4-4 WRIA 17 Groundwater Rights and Use, Consumptive Use Only 4-24
4-5 WRIA 17 Surface Water Rights and Use, Consumptive Use Only 4-35
4-6 Modeled Actual Evapotranspiration vs. Precipitation in WRIA 17 Lowland Areas 4-39
5-1 Total Spawning Escapement of Hood Canal And Eastern Strait of Juan De Fuca Summer Chum Stocks,1968 – 1998 5-6
5-2 Summer Chum Salmon Broodstock Collection at Quilcene Hatchery, 1912-1999 5-7
5-3 Fall Chum Salmon Spawning Escapement to Northern Hood Canal and Quilcene Bay Streams, 1968-1998 5-10
5-4 Spawning Escapement of Coho Salmon in Northern Hood Canal Streams, 1986 – 1999 5-12
5-5 Summary of WRIA 17 Generalized Salmonid Habitat Quality 5-27
8-1 Big Quilcene Sub-Basin 8-2
8-2. Fecal Coliform in Big Quilcene River, July 1986-January 1989 8-5
8-3 Big Quilcene River Diversion Near Qulcene: USGS Gage 12052210 Period of Record 1993-1999 8-10
8-4 Theoretical Optimum Habitat and Flow, Big Quilcene River Below Diversion near Quilcene: USGS Gage 12052210 Period of Record 1971-1972, 1994-1999 8-12
8-5 Big Quilcene Sub-basin Groundwater and Surfacewater Rights and Use, Consumptive Use Only 8-14
8-6 Summer Chum Salmon Spawning Escapement to the Big Quilcene River, 1970 – 1999 8-17
8-7 Fall Chum Spawning Escapement to the Big Quilcene River 8-18
8-8 Coho Spawning Escapement to Streams Entering Quilcene Bay and Dabob Bay, 1986 – 1998 8-19
9-1 Little Quilcene Sub-basin 9-2
9-2 Temperature and Fecal Coliform in Little Quilcene River (LQ3), July 1986-January 1989 9-5
9-3 Temperature and Dissolved Oxygen in Donovan Creek, December 1995 – December 1996 9-7
9-4 Fecal Coliform and Turbidity in Donavan Creek, December 1995 – December 1996 9-8
9-5 Dissolved Oxygen and Temperature in Jakeway Creek, December 1995 – December 1996 9-9
9-6 Theoretical Optimum Habitat and Flow, Little Quilcene River: Average Flow at Municipal Diversion Period of Record 1994 - 1999 9-13
9-7 Theoretical Optimum Habitat and Flow, Little Quilcene River: USGS Gage 12052200 Period of Record 1927, 1951-1956 9-14

LIST OF FIGURES (Continued)

9-8 Little Quilcene Sub-basin Groundwater and Surface Water Rights and Use, Consumptive Use Only 9-15
9-9 Fall Chum Spawning Escapement to the Little Quilcene River 9-18
9-10 Summer Chum Spawning Escapement to the Little Quilcene River 1970 – 1999 9-19
10-1 Dabob-Thorndyke Sub-Basin 10-2
10-2 Dabob-Thorndyke Sub-basin Groundwater and Surface Water Rights and Use, Consumptive Use Only 10-9
11-1 Ludlow Sub-Basin 11-2
11-2 Ludlow Sub-basin Groundwater and Surface Water Rights and Use, Consumptive Use Only 11-9
12-1 Chimacum Sub-Basin 12-2
12-2 Fecal Coliform Concentrations Chimacum Creek Main Stem, All Months 12-7
12-3 Fecal Coliform Concentrations Chimacum Creek Main Stem: Dry Months (June – October) . 12-8
12-4 Fecal Coliform Concentrations Chimacum Creek Main Stem, Wet Months (November – May) 12-9
12-5 Fecal Coliform, Conductivity and Turbidity Trends in Chimacum Creek, February 1988 – February 2000 12-10
12-6 Nitrate and Phosphate Trends in Main Stem Chimacum Creek, February 1988 – February 2000 12-11
12-7 Average Temperature and Dissolved Oxygen in Mainstem Chimacum Creek, January 1996 through February 2000 12-12
12-8 Fecal Coliform, Conductivity and Turbidity Trends in East Fork Chimacum Creek, February 1988 – February 2000 12-13
12-9 Nitrate and Phosphate Trends in East Fork Chimacum Creek, February 1988 – February 2000 12-14
12-10 Average Temperature and Dissolved Oxygen in East Fork Chimacum Creek, January 1996 – February 2000 12-15
12-11 Chimacum Creek Station CH/2.3 Flow Temperature Data: December 17, 1997 – September 17, 1999 12-16
12-12 Flow Exceedance: Chimacum Creek, USGS Gage 12051500 Period of Record 1952 - 1957 12-20
12-13 Theoretical Optimum Habitat and Flow: Chimacum Creek, Water Year 1998 12-21
12-14 Theoretical Optimum Habitat and Stream Flow Discharge: Chimacum Creek, Water Year 1999 12-22
12-15 Chimacum Sub-basin Groundwater and Surface Water Rights and Use, Consumptive Use Only 12-23
12-16 Coho Spawning Escapement to Chimacum Creek 12-27
13-1 Salmon-Snow Sub-Basin 13-2
13-2 Snow Creek Water Quality Trends, February 1988 – February 2000 13-6
13-3 Fecal Coliform Trends in Snow Creek, February 1988 – February 2000 13-7
13-4 Theoretical Optimum Habitat and Flows, Snow Creek near Maynard: USGS Gage 12050500 Period of Record 1952-1972, 1977-1984 13-12
13-5 Salmon-Snow Sub-basin Groundwater and Surface Water Rights and Use 13-13
13-6 Summer Chum Escapement to Salmon Creek and Snow Creek, 1973 – 1999 13-14
13-7 Coho Spawning Escapement and Smolt Production in Snow Creek 13-17
13-8 Steelhead Spawning Escapement and Smolt Production in Snow Creek 13-19
14-1 West Sequim Bay Sub-Basin 14-2
14-2 West Sequim Sub-Basin Groundwater and Surface Water Rights and Use, Consumptive Use Only 14-7
14-3 Summer Chum Spawning Escapement to Jimmycomelately Creek, 1974 – 1999 14-9
14-4 Coho Spawning Escapement to Jimmycomelately Creek, 1984 – 1999 14-11

LIST OF FIGURES (Continued)

15-1 Miller Sub-basin 15-2
15-2 Miller Sub-basin Groundwater and Surface Water Rights and Use, Consumptive Use Only 15-7
16-1 Quimper Sub-basin 16-2
16-2 Quimper Sub-basin Groundwater and Surface Water Rights and Use, Consumptive Use Only 16-7
17-1 Indian Marrowstone Sub-Basin 17-2
17-2 Indian-Marrowstone Sub-basin Groundwater and Surface Water Rights and Use, Consumptive Use Only 17-7

LIST OF TABLES

ES-1 Candidate 1998 Section 303(d) List for WRIA 17 xxii
ES-2 Comparison of Water Rights and Claims by Sub-basin to Volume of Surface and Groundwater xxviii
ES-4 Summary of sub-estuarine habitat quality for streams in Watershed Resource Inventory Area 17 xxxii
ES-3 Summary of Fish Habitat Assessment Data by Sub-Basin xxxi
ES-5 Summary of Population Projection and Distribution, and Potential Impact on Water Demand. xxxviii
1-1 Summary of Generalized Land Use (in acres) by Sub-Basin 1-4
1-2 WRIA 17 20-Year Population Projection and Distribution 1-5
2-1 Available Climate Records within WRIA 17 2-2
2-2 Other Climate Stations Used in Study 2-2
3-1 Water Quality Standards for Freshwater (WAC 173-201A) 3-2
3-2 Water Quality Standards for Marine Water (WAC 173-201A) 3-2
3-3 Candidate 1998 Section 303(d) List for WRIA 17 3-5
3-4 Data used for groundwater quality analysis 3-8
3-5 Chloride data summary 3-10
3-6 Nitrate data summary 3-11
4-1 Zoning Codes and Model Land-Cover Categories 4-5
4-2 Recharge Estimates for WRIA 17 4-9
4-3 Stream Gaging Stations within WRIA 17 with Daily or Monthly Records 4-17
4-4 Summary of Consumptive Groundwater Rights in WRIA 17 4-22
4-5 Groundwater Applications by Sub-Basin and Purpose of Use 4-25
4-6 Groundwater Claims by Sub-Basin and Purpose of Use 4-26
4-7 Population Based Estimates of Single Family Domestic Wells 4-28
4-8 Reported Groundwater Use from Water System Plans 4-29
4-9a Estimate of Groundwater Use Assuming 180 gpd per Residential Hookup 4-30
4-9b Estimate of Groundwater Use Assuming 250 gpd per Residential Hookup 4-31
4-10a Summary of Surface Water Rights, in WRIA 17 Consumptive Use Only 4-33
4-10b Surface Water Use City of Port Townsend/Port Townsend Paper Company 4-36
4-11 Estimated Preliminary Water Budget by Sub-Basin 4-37
4-12 Comparison of Water Rights and Claims by Sub-basin to Volume of Surface and Groundwater 4-40
4-13 Summary of Population Projection and Distribution, and Potential Impact on Water Demand 4-52
5-1 The status of Hood Canal and Strait of Juan de Fuca salmon and steelhead stocks in WRIA 17 as determined by the Salmon and Steelhead Stock Inventory and Assessment 5-3
5-2 Five-year average spawning escapement and total abundance for Hood Canal summer chum stocks 5-5
5-3 Five year average spawning escapement and total abundance for Strait of Juan de Fuca summer chum stocks 5-8

LIST OF TABLES (Continued)

5-4 Evaluation of Habitat Assessment Methods on a Simple Numerical Scale (1 – poor, 2 – fair, 3 – adequate) 5-18
5-5 Summary of Sub-Estuarine Habitat Quality for Streams in WRIA 17 5-20
5-6 Summary of Fish Habitat Assessment Data by Sub-Basin 5-21
5-7 Factors for Decline of Summer Chum Salmon in WRIA 17 Streams of Hood Canal and the Eastern Strait of Juan De Fuca (from Ames et al. 2000) 5-22
5-8 Rating of the Effect of Habitat Degradation Factors on Coho Salmon Productivity in WRIA 17 Streams (PNPTC Unpublished Data 1997) and Salmonids in General 5-23
5-9 Tree Diameter (DBH) Distribution in the Riparian Zone of Summer Chum-Bearing Streams in WRIA 17 5-24
5-10 Riparian Forest Species Composition for Summer Chum-Bearing Streams in WRIA 17. 5-24
5-11 Riparian Forest Buffer Width for Summer Chum-Bearing Streams in WRIA 17 5-24
5-12 Summary of Habitat Data Collected from Salmon Creek, the Little Quilcene River, and the Big Quilcene River in 1992 5-25
5-13 Potential Habitat Gained by Removing Barrier to Fish Passage at Road Crossing Sites in Eastern Jefferson County 5-29
6-1 Summary of Instream Flow Recommended Presented by Ecology and WDFW, using the Toe-Width Method 6-3
6-2 Instream Flow Incremental Method (IFIM) study results for the Big Quilcene River 6-6
6-3 Summary of instream flow recommended in WRIA 17 presented by U.S. Fish and Wildlife Service (Hiss 1993) 6-7
8-1 Surface Water Features in the Big Quilcene Sub-basin 8-1
8-2 Big Quilcene Sub-basin Land Use 8-3
8-3 Surface Water Quality Data Available for Big Quilcene Sub-basin 8-4
8-4 Freshwater Quality Data Available for the Big Quilcene River 8-6
8-5 Marine Water Quality Data Available for the Big Quilcene Sub-basin 8-6
8-6 Fecal Coliform Monitoring in Quilcene Bay, 1994-1998 8-7
8-7 Analysis of Surface Water Allocation in Big Quilcene Sub-basin 8-13
8-8 Summary of Completed Restoration Projects in the Big Quilcene Sub-basin 8-27
9-1 Fresh Water Features in the Little Quilcene Sub-basin 9-1
9-2 Little Quilcene Sub-basin Land Use 9-3
9-3 Water Quality Data Available for the Little Quilcene Sub-basin 9-4
9-4 Summary of Little Quilcene Sub-basin Fecal Coliform Monitoring Data 9-4
9-5 Water Quality Results for Streams in the Little Quilcene Sub-basin (JCCD 2000) 9-6
9-6 Little Quilcene River Water Quality Testing 9-10
9-7 Analysis of Surface Water Allocation in Little Quilcene Sub-basin 9-16
9-8 Summary of Completed Restoration Projects in the Little Quilcene Sub-basin 9-24
10-1 Fresh Water Features in the Dabob-Thorndyke Sub-basin. 10-1
10-2 Dabob-Thorndyke Sub-basin Land Use. 10-3
10-3 Water Quality Data Available for Dabob-Thorndyke Sub-basin 10-4
10-4 Tarboo Creek Fecal Coliform Monitoring Data 10-4
10-5 Fecal Coliform Monitoring in Thorndyke and Dabob Bays for 1993-1998 10-5
10-6 Fecal Coliform Monitoring Results in Dabob Bay for 1986-1989 10-6

LIST OF TABLES (Continued)

10-7 Analysis of Surface Water Allocation in Dabob-Thorndyke Sub-basin 10-8
10-8 Summary of Completed Restoration Projects in the Dabob-Thorndyke Sub-basin 10-12
11-1 Fresh Water Features in the Ludlow Sub-basin 11-2
11-2 Ludlow Sub-basin Land Use 11-4
11-3 Surface Water Quality Data Available for the Ludlow Sub-basin 11-4
11-4 WRIA 17 Ludlow Sub-basin Marine Water Quality Data Available 11-5
11-5 Fecal Coliform Monitoring Results in Port Ludlow for 1994-1998 11-5
11-6 Summary of Non-Point Source Pollution in the Ludlow Sub-Basin 11-7
11-7 Analysis of Surface Water Allocation in Ludlow Sub-basin 11-10
11-8 Summary of Completed Restoration Projects in the Ludlow Sub-basin 11-12
12-1 Fresh Water Features in the Chimacum Sub-basin 12-1
12-2 Chimacum Sub-basin Land Use 12-3
12-3 Surface Water Quality Data Available for the Chimicum Sub-basin 12-4
12-4 Water Quality Data for Chimicum Sub-basin (JCCD 2000) 12-5
12-5 Fecal Coliform Monitoring Results in Port Townsend Bay for 1993-1998 12-17
12-6 Analysis of Surface Water Allocation in Chimacum Sub-basin 12-24
12-7 Summary of Completed Restoration Projects in the Chimacum Sub-basin 12-30
13-1 Surface Water Features in the Salmon-Snow Sub-basin 13-1
13-2 Salmon-Snow Sub-basin Land Use 13-4
13-3 Surface Water Quality Data Available in the Salmon-Snow Sub-basin 13-5
13-4 Water Quality Data Results for Salmon-Snow Sub-basin 13-5
13-5 Salmon-Snow Creeks Fecal Coliform Monitoring Data 13-8
13-6 DOH Fecal Coliform Monitoring Results in Discovery Bay for 1993-1998 13-9
13-7 Summary of Non-Point Source Pollution in the Salmon-Snow Sub-Basin 13-10
13-8 Analysis of Surface Water Allocation in Salmon-Snow Sub-basin 13-15
13-9 Summary of Completed Restoration Projects in the Salmon-Snow Sub-basin 13-23
14-1 Fresh Water Features in the West Sequim Sub-basin 14-1
14-2 West Sequim Bay Sub-basin Land Use 14-3
14-3 Miller Sub-basin Land Use 15-3
15-2 Summary of Non-Point Source Pollution in the Miller Sub-basin 15-4
15-4 Analysis of Surface Water Allocation in Miller Sub-basin 15-6
16-1 Quimper Sub-basin Land Use 16-2
16-2 Summary of Non-point Source Pollution in the Quimper Sub-basin 16-4
16-3 Analysis of Surface Water Allocation in Quimper Sub-basin 16-6
17-1 Indian - Marrowstone Sub-basin Land Use 17-3
17-2 DOH Fecal Coliform Monitoring Results in Killisut Harbor for 1993-1998 17-3

EXECUTIVE SUMMARY

This Stage 1 Technical Assessment summarizes information for Watershed Resource Inventory Area (WRIA) 17 and represents the most current compilation and review of existing water quality, water resource, fisheries habitat and instream flow data for the area. This Stage 1 Technical Assessment represents the first step in the technical review and analysis of potential water quality, water resource and fisheries habitat in WRIA 17. It should be noted that Clallam County submitted additional information to the Planning Unit after the draft Stage 1 Assessment was completed. It is expected that this information will be incorporated into future data summaries and technical assessments. As such, this report is not designed or intended to provide a complete analysis and or summary of the full array of potential water related issues in the WRIA. This Stage 1 assessment will be followed by subsequent stages of assessment, and eventual preparation of a watershed plan.

This Stage 1 Technical Assessment has been initiated by the WRIA 17 Planning Unit, which is comprised of Jefferson and Clallam counties, the City of Port Townsend, affected Native American tribes, special purpose districts, state agencies, public non-profit organizations, and private industry. The scope of this assessment has been established by the Planning Unit, consistent with the requirements of the Watershed Management Act (RCW 90.82/ESHB 2514). The assessment has been funded in part by the Washington Department of Ecology.

PURPOSE AND SCOPE

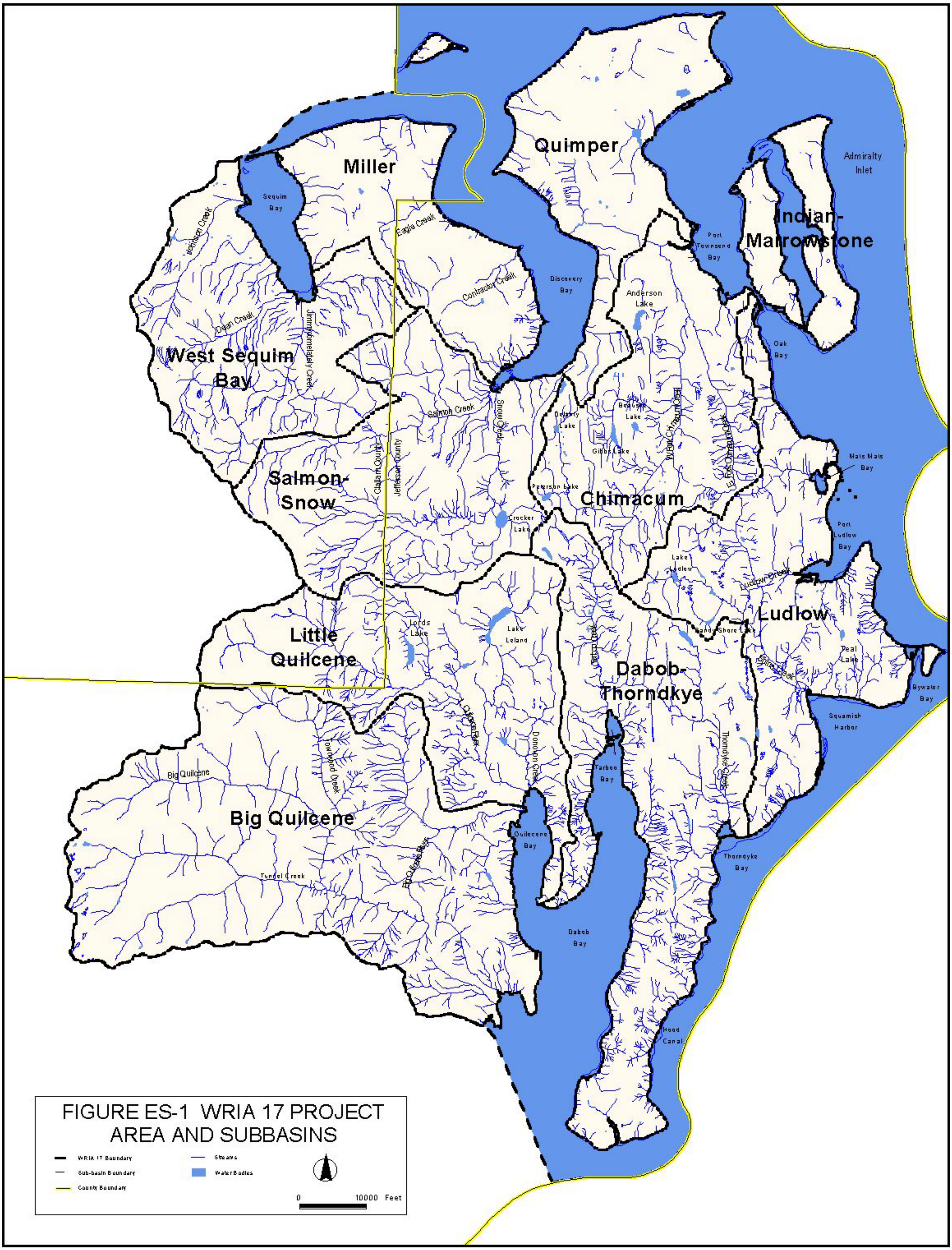
The general purpose of Stage 1 of the Technical Assessment is to summarize existing watershed information, assess potential growth impacts, identify additional data gaps and prepare a Stage 1 assessment report. This report addresses and evaluates information from previous published watershed studies, water quality reports and data available from existing databases, and describes marine and surface water quality in each of the following 10 sub-basins:

Big Quilcene	Little Quilcene	Dabob/Thorndyke
Salmon-Snow	Chimacum	Ludlow
Quimper	West Sequim Bay	Indian/Marrowstone
Miller		

Available data vary between sub-basins. Each sub-basin includes a description of general sub-basin characteristics, land-use, water use, hydrogeology, habitat, water quality, and drainage, as well as identification of sub-basin specific data gaps.

WRIA 17 STUDY AREA DESCRIPTION

The WRIA 17 area covers approximately 401,000 acres and includes portions of Jefferson and Clallam County (Figure ES-1). Over 290,000 acres (70 percent) of the WRIA are privately owned. Property owned by the federal government covers approximately 74,000 acres (20 percent), while state property covers 35,000 acres (10). Major physical features of the WRIA 17 area include portions of Hood Canal and Puget Sound, the Strait of Juan de Fuca, and the northeast flank of the Olympic Mountains. The WRIA has a population of approximately 23,800 people with the primary population center of Port Townsend.


Miller
Quimper
Indian-Marrowstone
West Sequim Bay
Salmon-Snow
Chimacum
Little Quilcene
Ludlow
Dabob-Thorndkye
Big Quilcene
Sequim Bay
Discovery Bay
Port Townsend Bay
Admiralty Inlet
Oak Bay
Mats Mats Bay
Port Ludlow Bay
Bywater Bay
Squamish Harbor
Thorndyke Bay
Tarboo Bay
Quilcene Bay
Dabob Bay
Hood Canal
Anderson Lake
Beaver Lake
Gibbs Lake
Peterson Lake
Crocker Lake
Lake Ludlow
Teal Lake
Lords Lake
Lake Leland
Clallam County
Jefferson County
Big Quilcene
Tunnel Creek
Townsend Creek
Dosewallips River
Dosewallips Creek
Thorndyke Creek
Salmon Creek
Snow Creek
Eagle Creek
Contractor Creek
Ludlow Creek
Chimacum Creek
W Fork Chimacum Creek
E Fork Chimacum Creek
Jimmycomelately Creek
Dean Creek
Johnson Creek
FIGURE ES-1 WRIA 17 PROJECT AREA AND SUBBASINS
WRIA 17 Boundary
Sub-basin Boundary
County Boundary
Streams
Water Bodies
0
10000 Feet

Geologically, WRIA 17 is generally characterized by glaciated steep terrain to low mountains with high gradient streams. Soils tend to be deep to moderately deep loams, with areas of silt and clay. Vegetation ranges from pasture in lowland valleys to predominantly alder and conifers at higher elevations.

WATER QUALITY

Surface Water Quality

The surface water quality assessment describes marine and surface water quality and includes identification and analysis of water quality limited stream segments, previous monitoring locations, and point and non-point pollution sources.

In general, surface water quality in WRIA 17 is good where it has been measured, although areas of water quality degradation have been identified. Surface water quality monitoring conducted by Jefferson County, the Jefferson County Conservation District (JCCD), the Point No Point Treaty Council (PNPTC), the Washington Department of Health (DOH) and others indicates that the majority of freshwater streams and marine water meet state standards for the parameters measured. The majority of marine and freshwater water quality information collected in WRIA 17 has consisted of fecal coliform (FC) bacteria and temperature data. There is a fair amount of data on physical characteristics such as dissolved oxygen (DO), pH, conductivity, total suspended solids (TSS), and turbidity. There is limited information on nutrients such as total phosphorous (TP) and nitrate (NO3-N). Very little information is available on organic or inorganic toxic compounds.

Under Section 303(d) of the Clean Water Act, the Washington Department of Ecology (Ecology) identifies water bodies that do not meet water quality standards. This list is known as the 303(d) list. The candidate 1998 Section 303(d) List for WRIA 17 is shown in Table ES-1 and identifies over 64,000 feet (over 12 miles) of stream with impaired uses.

Table ES-1. Candidate 1998 Section 303(d) List for WRIA 17

			On 303(d) List ?		
Water Body	**Parameter**	**Location**	**1998**	**1996**	**1994**
Big Quilcene River	Fish Habitat	RM 2.8	Yes	Yes	No
Big Quilcene River	Instream Flow	RM 2.8	Yes	Yes	No
Chicken Coop Creek	Fecal Coliform	Mouth	Yes	Yes	Yes
Chimacum Creek	Temperature	RM 1.0, 3.5, 8.8	Yes	Yes	No
Chimacum Creek	Fecal Coliform	Station 17B100	Yes	Yes	Yes
Dabob and Quilcene Bay	Fecal Coliform	Station 19	Yes	Yes	Yes
Donovan Creek	Temperature	RM 0.2	Yes	No	No
Jackson Creek	Fish Habitat	Mouth	Yes	Yes	No
Johnson Creek	Fecal Coliform	Mouth	Yes	Yes	Yes
Leland Creek	Temperature	RM 0.2	Yes	No	No
Little Quilcene River	Temperature	RM 2.0	Yes	No	No
Marple Creek	Fish Habitat	Mouth	Yes	Yes	No
Ripley Creek	Temperature	RM 0.2	Yes	No	No
Sequim Bay	Dissolved Oxygen	Ecol Station JDF005	Yes	Yes	Yes
Sequim Bay	pH	Ecol Station JDF005	Yes	Yes	Yes
Sequim Bay	PAHs (sediment)	Lat. 48.075, Long. 123.045	Yes	Yes	Yes
Tarboo Creek	Temperature	RM 2.5, RM 0.5	Yes	Yes	No
Thorndyke Creek	Temperature	RM 1.1	Yes	No	No

Source: Candidate 1998 Section 303(d) List Decision Matrix and Ecology (1995).

The Clean Water Act requires Ecology to develop total maximum daily loads (TMDLs) for 303(d) listed waters. A TMDL is a water cleanup plan that includes an analysis of how much pollution a water body can receive and still remain within the standards for the intended uses. The maximum load is the sum of all point and non-point source discharges as well as natural background loading that will not exceed the loading capacity of the water body. To date, no TMDLs have been established or planned for any impaired WRIA 17 water bodies; however, Ecology has identified that seven TMDL studies are required in WRIA 17 based on the 1998 303(d) list. Specific areas include:

- Fecal coliform (FC) in Chicken Coop Creek, Chimacum Creek, Dabob Bay and Jackson Creek,
- High temperature in Chimacum Creek, Donovan Creek, Leland Creek, Little Quilcene River, Ripley Creek, Tarboo Creek and Thorndyke Creek,
- Low in-stream flow in the Big Quilcene River, and
- Dissolved oxygen and pH in Sequim Bay.

Potential Surface Water Pollutant Sources

Potential pollutant sources in WRIA 17 include both point and non-point sources. A total of 114 point sources are located in the WRIA that are currently regulated by individual National Pollutant Discharge Elimination System (NPDES) permits. These point sources include wastewater and stormwater discharges to marine and freshwater receiving waters, as well as discharges to municipal wastewater systems. Data to evaluate potential trends and specific impacts of these individual point sources were not available for this analysis.

Non-point sources in the WRIA are less well characterized, and generally include a combination of agriculture, on-site septic (OSS), forestry, and urban stormwater run-off. The location of these non-point sources is approximated based on existing data and maps from previous reports. Specific non-point sources, to the extent previously identified, have been evaluated for each sub-basin.

Correction of non-point pollution sources has been aggressively pursued in several sub-basins. Jefferson County and the JCCD have corrected more than 30 OSS in the Quilcene Bay watershed. To restrict livestock access to streams, the JCCD oversaw 14,000 feet of fencing in the Little Quilcene sub-basin, 20,000 feet in the Dabob-Thorndyke sub-basin, 11,000 feet in the Salmon-Snow sub-basin, and 53,000 feet in the Chimacum sub-basin since 1988. Non-point source corrective actions in other sub-basins may also have been completed but not documented.

Groundwater Quality

The quality of groundwater in WRIA 17 was evaluated by reviewing existing studies and compiling readily available water-quality data. The most common parameters of concern in WRIA 17 are chloride, nitrate, iron and manganese. Chloride is commonly used as an indicator of saltwater intrusion, and most studies addressing chloride concentrations focus on coastal areas. Elevated concentrations of nitrate typically indicate contamination from septic leachate, animal wastes or fertilizer applications. Iron and manganese occur from natural sources and can compromise aesthetic qualities of water at higher concentrations. Reported incidents of groundwater contamination caused by human activities were also examined.

Data sources for this report include existing studies performed by Department of Ecology (Ecology), the United States Geological Survey (USGS), and various consultants. In addition, raw chloride and nitrate

data maintained by Jefferson County Health Department, Clallam County Department of Community Development, Ecology, USGS, and consultants reports were compiled together into a single database, thus allowing them to be viewed together in a single "big picture". Overall, available data indicate that water quality is generally good for the chemical constituents reviewed. Elevated chloride can be problematic in coastal areas, and is sometimes noted in inland areas. Nitrate concentrations are generally far below State drinking water standards and do not pose a health threat. While elevated iron and manganese are common complaints, these constituents are not considered to be health related. Groundwater has been contaminated by human activities at selected locations, but available data do not suggest that existing drinking water supplies have been impaired.

Elevated chloride concentrations in coastal areas are typically associated with saltwater intrusion. Intrusion implies that groundwater withdrawals have shifted the balance between fresh groundwater and salty groundwater to cause higher chloride concentrations along the coast. Not all elevated chloride concentrations are due to the impact of groundwater withdrawals. In some cases, wells have been completed too close to the coast in already salty portions of the aquifer. In these cases, the effect of pumping is still to increase chloride concentrations in the vicinity of the pumping well. In other cases, wells may be completed in portions of the aquifer in which naturally salty groundwater is "trapped" due to lack of sufficient "flushing". These wells are more typical in inland locations but may also occur near the coast. In inland locations, these wells are typically not susceptible to saltwater intrusion as a result of groundwater withdrawal.

Isolated instances of coastal wells with elevated chloride concentrations are found in all sub-basins with significant coastal exposure. While isolated instances of high chloride in coastal wells suggest that caution should be exercised in developing groundwater in the same location and from the same water-bearing zone, they say little about the severity of saltwater intrusion potential in that sub-basin. Some sub-basins, however, show a notably high incidence of wells with elevated chloride concentrations. High chloride is common over much of Marrowstone Island, along portions of the Ludlow sub-basin coastline, in inland locations in the Big and Little Quilcene sub-basins, along west Sequim Bay, and near Gardiner in the Miller sub-basin. It is not uncommon to see areas with some wells exhibiting high chloride and others nearby showing "background" (non-intruded) values. The factors controlling saltwater intrusion are multiple and complex, and vary with hydrogeologic conditions and pumping withdrawals. In some areas it may be possible to find water-bearing zones with varying saltwater intrusion potentials.

Nitrate concentrations measured in WRIA groundwater are predominantly within natural "background" concentrations (82 percent) or are only slightly elevated from background concentrations (10 percent). The remaining wells showing elevated nitrate concentrations are typically distributed in a "spotty" fashion with no discernible geographic pattern. Among all of the sub-basins, the occurrence of elevated nitrate is most notably apparent in the Indian-Marrowstone, Chimacum, Dabob-Thorndyke, and Little Quilcene sub-basins followed by the Quimper and Ludlow sub-basins.

Elevated iron and manganese concentrations are commonplace in the groundwater of WRIA 17. Various studies document that significant portions of the total wells sampled show elevated concentrations. While any new well has a relatively high chance of encountering elevated iron or manganese, the sub-surface conditions which control iron and manganese concentrations are complex and cannot be easily predicted.

Seven known or suspected cases of groundwater contamination from hazardous/contaminated sites were identified during literature review for this study. Three occur at the U.S. Navy installation on Indian Island, three in Port Townsend, and one suspected in Quilcene. A wide range of groundwater contaminants were reported, including heavy metals, halogenated organics, non-halogenated solvents, PCB's, pesticides, petroleum products, and other unspecified organic matter. In addition, thirteen sites

were listed where leaking underground storage tanks have contaminated groundwater with petroleum products. The sites occur in Port Townsend, Nordland, Chimacum, Port Ludlow, and Quilcene.

WATER QUANTITY

The general status and overall conditions of surface water and groundwater quantity and use in WRIA 17 was examined using existing information on groundwater and surface water quantity, precipitation, water demand, allocated water (rights, claims and applications) and potential effects of land use. Information on water quantity and use includes tabulation of existing data, analysis of potential trends, and plotting of data and model results on Geographic Information System (GIS) based maps. New data and analysis of potential groundwater recharge areas, and areas of potential hydraulic continuity have also been developed. Sub-basin specific discussions of specific water quantity are provided, as are identification of potential data gaps and recommendations for further study.

Water Allocation and Use

Groundwater rights in WRIA 17 amount to 8,096 af/yr, and are primarily issued for domestic (56 percent), municipal (16 percent) and irrigation (15 percent) uses. The largest water right allocations are found in the Chimacum and Quimper sub-basins. Water-right claims potentially represent an additional 1,844 af/yr of allocations; however, the number of these claims currently active are unknown. Exempt water rights, associated with individual wells in the WRIA, could also represent a significant allocation that are not included with rights currently documented by Ecology. Tribal water rights are unquantifited and are senior to all existing water rights.

Actual groundwater use in WRIA 17 is estimated to be between 5,749 and 5,253 af/yr. About 2,765 af/yr are estimated for domestic and commercial use, and are believed to be high quality estimates. The remaining 2,984 af/yr is predominantly used for irrigation, and is not considered to be as accurate an estimation.

The surface water rights review focused on consumptive use water rights which account for 3,468 af/yr. The majority of the surface water used in the WRIA is from the Big Quilcene and Little Quilcene Rivers. The predominate use is by municipalities and manufacturing (City of Port Townsend – 87 percent) followed by irrigators (13 percent).

Groundwater Recharge

Groundwater recharge was estimated in WRIA 17 using a combination of GIS analysis and a proprietary spreadsheet model for tracking soil moisture developed by Pacific Groundwater Group, Inc. (PGG). Precipitation, soil properties, surficial geology, and land cover were taken into consideration. Total recharge of 140,000 af/yr was estimated for the WRIA. A wide range of recharge rates was estimated for areas where till was absent, whereas recharge through till never exceeded 12 to 14 in/yr. Recharge was highest in the Dabob-Thorndyke and Ludlow sub-basins, and was relatively low in bedrock dominated sub-basins such as the Big Quilcene and Little Quilcene.

Recharge shows the highest seasonal variation in areas where till is absent. In till covered areas, water is predicted to perch above the till and seep slowly downwards to underlying aquifers over most of the year. Although recharge is seasonal in portions of the WRIA, groundwater availability typically does not exhibit the same seasonality. This is because aquifers tend to function as reservoirs, with summer withdrawals replenished by winter recharge.

Extended droughts and periods of high precipitation are noted from long-term records from climatic monitoring stations in and around WRIA 17. Recharge rates in the northern portion of the WRIA, where rainfall rates are lowest, appears to be highly sensitive to variations in precipitation. Recharge in areas farther south, where rainfall is greater, is less sensitive to periods of drought. Monitoring and historic reports are generally the best way to determine how sensitive a particular aquifer system is to drought conditions.

Approximately 3 percent of estimated groundwater recharge appears to be withdrawn for human use in the WRIA. Known allocations represent between 6 percent and 17 percent of estimated recharge, and are more realistically assessed at the lower end of this range. While it is apparent that groundwater recharge far exceeds actual use, this conclusion should not be used to evaluate groundwater availability on a site-by-site basis. The proportion of groundwater recharge that helps to maintain baseflow in streams and offsetting saltwater intrusion along the coast has not been estimated. In addition, water budgets alone should not be used to determine groundwater availability. More detailed hydrogeologic analysis should be considered to predict the effects of pumping, and tolerable ranges or levels of impacts should be identified and defined for hydrologic features of potential concern.

Application of the recharge model to WRIA 17 is intended to provide reasonable estimates of recharge inflows; however, on the local scale, natural variation and parameter uncertainty dictate that recharge estimates be seen as approximate. Recharge estimates should not be used to estimate groundwater availability for pumping withdrawls on either local or regional scales.

Hydraulic Continuity

A preliminary evaluation of the potential for hydraulic continuity was performed by designing a ranking factor, called the "relative hydraulic continuity potential" (RHCP), and applying it to streams in the WRIA. A high ranking indicates that streams have a high likelihood for continuity with an area's principal aquifer system. A medium ranking indicates a high likelihood of hydraulic continuity with shallow, localized aquifers and less (or no) continuity to principal aquifers. A low ranking indicates little or no hydraulic continuity with shallow or principal aquifers.

The RHCP rankings were based on geologic information alone, and generally did not incorporate hydrogeologic or hydraulic considerations due to lack of available hydrogeologic evaluation. Hydrogeologic studies, and their implications regarding hydraulic continuity, were discussed where available. Actual hydrogeologic conditions and hydraulic analyses can provide a reliable basis for improving the accuracy of the RHCP rankings, and actual hydraulic continuity can vary among water-bearing zones within a groundwater flow system. The RHCP rankings assigned in this report reflect relative potential, and should be augmented with more detailed hydrogeologic analysis where stream baseflows represent potential habitat or other concerns.

Higher rankings of RHCP occur predominantly in the Ludlow, Dabob-Thorndyke, and Chimacum sub-basins. Localized high rankings were also noted at the mouth of the Big and Little Quilcene Rivers, and along an isolated stream on the Quimper Peninsula. Medium and low rankings were assigned along streams in most other areas, due to their locations within shallow alluvial or outwash channels above till or bedrock, or directly over till or bedrock.

Surface Water Quantity

A review of climate and stream gaging data was performed for this assessment. The number and distribution of stream gaging stations was not sufficient to perform analyses on most streams in the WRIA. For the data that could be analyzed, statistical analyses of the gaging record was performed to

estimate the streamflow that would occur during dry, median and wet years. "Theoretical optimal habitat", or optimum instream flowss were compared to the estimated streamflows. It was found that most of the optimal instream flows far exceed streamflows expected during median years and also exceed expected wet year streamflow during much of the time optimal flows are predicted to be needed.

Preliminary Water Budget

A water budget analysis is a useful tool to relate natural components of the hydrologic system to existing withdrawals and/or allocations. The water budget is a conceptual tool for understanding the pathways by which water enters, flows through, and leaves a watershed. It can provide a useful starting point for consideration of water quantity, water quality, and habitat issues. Water budgets, however, cannot be rigorously used to assess resource availability because they do not allow prediction of system response to additional withdrawals.

A water budget is an assessment of the major components of a hydrologic system and includes the interactions between surface water and groundwater systems. This preliminary assessment can provide a general understanding of the magnitude of the recharge and selected discharge components. In general, however, it does not provide an accurate assessment of surface water/ground water interactions and quantities and should therefore not be relied on as the sole tool for water resource management.

A simplified water balance can be summarized as follows:

Precipitation = Runoff + Groundwater Recharge + Evapotranspiration

Sub-basin data for these water budget components are not currently available in much of WRIA 17. In addition, there are a number of other components of a water budget that need to be addressed if a detailed review of surface and groundwater resources is desired. Those components include groundwater and surface water uses, groundwater discharge to saltwater, spring discharge (especially near the coast), change in groundwater storage, timing of groundwater discharge and others.

It is important to note that the simplified water budget described in this Stage 1 assessment does not fully capture all-important elements of the movement of water through WRIA 17 sub-basins. For example, some sub-basins include substantial importation of water from other sub-basins through pipelines or storage in reservoirs. In addition, groundwater flow does not always follow the same divides as surface water flow. Therefore, groundwater may flow into or out of a sub-basin or across sub-basin and even WRIA boundaries. The water balance of an aquifer system is not a fixed condition. It will change seasonally and from year to year. All the components of the water balance can deviate dramatically over time from natural and/or from human activities.

Over 5,000 wells extract groundwater for various uses. Annual extraction of groundwater in the WRIA is estimated at 5,749 acre-feet per year (af/yr). Groundwater rights and claims total 9,940 af/yr. Exempt water rights for single domestic wells in the WRIA could amount to as much as 28,000 af/yr; however, the likelihood that this quantity of water is actually used is extremely low. Groundwater recharge predicted for the entire WRIA is on the order of 140,000 af/yr. These numbers suggest that actual groundwater use represents about 4 percent of recharge, and that legally allowable groundwater use (i.e. allocations) represents between 6 percent of recharge (based on non-exempt water rights) and as much as 28 percent of recharge (should all claims, exempt and non-exempt rights be perfected). Table ES-2 presents the available data for water budget components and use estimates for each WRIA 17 sub-basin. While it is apparent that groundwater recharge far exceeds actual use, this conclusion should not be used to evaluate groundwater availability on a site-by-site basis.

Table ES-2. Comparison of Water Rights and Claims by Sub-basin to Volume of Surface and Groundwater

Sub Basin Name	Est. Groundwater Recharge (ac-ft/yr.)	Groundwater		Total Rights and Claims (ac-ft/yr.)	Net Ground-water (ac-ft/yr.)	Est. Surface Water Runoff (ac-ft/yr.)	Surface Water		Total Rights and Claims .(ac-ft/yr.)	Net Surface-water (ac-ft/yr.)	Pending Application		
		Rights (ac-ft/yr.)	Claims (ac-ft/yr.)				Rights (ac-ft/yr.)	Claims (ac-ft/yr.)			Groundwater (GPM)	Surface Water (cfs)	Total Appl. (GPM)
Big Quilcene	10,279	712	90	802	9,477	150,000	22,244	286	22,530	127,470	2,020	0	2,020
Little Quilcene	14,652	70	88	158	14,494	40,000	445	170	615	39,385	569	0	574
Dabob-Thorndyke	39,743	491	20	511	39,232	N/A	83	208	291	N/A	120	2	813
Ludlow	21,237	1,407	864	2,271	18,966	N/A	582	152	734	N/A	473	1	721
Chimacum	18,712	2,124	348	2,472	16,240	30,000	580	702	1,282	28,718	745	0	745
Salmon-Snow	9,461	19	10	29	9,432	N/A	258	192	450	N/A	0	0	0
West Sequim	6,478	368	60	428	6,050	N/A	809	70	879	N/A	0	0	0
Miller	8,115	1,045	116	1,161	6,954	N/A	146	24	170	N/A	1,740	0	1,740
Quimper	8,980	1,817	84	1,901	7,079	N/A	0	180	180	N/A	460		460
Indian-Marrowstone	3,002	42	164	206	2,796	N/A	0	8	8	N/A	0	0	9
Totals	140,659	8,095	1,844	9,939	130,720	220,000	25,147	1,992	27,139	195,573	6,127	2	7,082

Notes:

Water rights allocations based on Water Rights Information System (WRIS) data obtained from Jefferson County.

Surface water runoff is approximate.

Application quantity represent instantaneous withdrawal rates (Qi) expressed in gallons per minute (GPM) for ground water applications and cubic feet per second (cfs) for surface water applications.

Many other factors should be considered prior to making site-specific water decisions including the groundwater-surface water flow system, well location, and potential effects of pumping. While it may seem like ample recharge is available to support these other components of the groundwater flow system, such an evaluation must be made on a case-by-case basis.

Diversion of surface water for beneficial use in WRIA 17 is not extensive. The only major diversion is the City of Port Townsend, which provides about 22 cfs or 16,000 acre-feet (af) of surface water per year. It is estimated that the surface water use in streams other than the Big and Little Quilcene Rivers is 20 to 40 cfs. Total surface water rights and claims in the WRIA amount to 109 cfs and 5,460 af/yr. The annual use numbers for water rights applications is likely low because of the lack of information contained in the water rights database.

Very little surface water data are available to enable a comparison of surface water quantity to use. The sub-basins with some streamflow data are the Big Quilcene and Little Quilcene Rivers and Chimacum Creek. For the Big Quilcene River, the estimated diversions are approximately 12,900 af/yr by the City of Port Townsend. The total annual runoff is approximately 150,000 af/yr at the mouth of the river. That estimated volume of runoff does not include the City's diversion. The City diverts about 8 percent of the total flow in the Big Quilcene River on an annual basis. That ratio varies substantially depending on demands and streamflow present in the Big Quilcene River.

On the Little Quilcene River, the estimated runoff is 40,000 af/yr at its mouth. The City diverts about 3,000 af/yr, or about 7 percent of the flow on an annual basis. That diversion ratio also varies substantially depending on demands and streamflow present in the Little Quilcene River. On Chimacum Creek, the estimated runoff is approximately 30,000 af/yr. Surface water demands are not well characterized in this sub-basin. Based upon water rights records, 580 af/yr are allocated, which is approximately 2 percent of the total volume of runoff on an annual basis. However the demands occur during the summer period when streamflows are low and are likely a much greater percentage of flow than indicated.

Conservation Options

Water resources to support future growth in WRIA 17 will be partially dependent on recognizing the value of water resources and the implementation of effective conservation plans. Conservation is a central element of State law, and is directed at both suppliers and consumers of water, and local Comprehensive Water Plans must incorporate conservation elements. With the exception of the City of Port Townsend water system, water withdrawals in WRIA 17 are typically geographically dispersed and individually small. For this reason, water conservation options for WRIA 17 would be expected to focus primarily on non-structural measures that improve water use efficiencies such as teired rate strucutres, conservancy boards, and education. Low water use fixtures, water re-use and enhanced water storage may also increase water conservation potential.

HABITAT AND STOCK ASSESSMENT

The habitat and stock assessment describes the species of salmonid fishes that live in the streams and rivers within WRIA 17, their life history, and their habitat requirements at each stage of freshwater life. The current status of fish populations, (i.e. the recent trend in their abundance) and the condition of their habitat is generally summarized and described in detail for each sub-basin, to the extent that reliable information exists. The data summary is based on a variety of information sources. Fish abundance trends are drawn largely from annual assessments conducted by the Washington Department of Fish and Wildlife (WDFW), tribal fisheries management agencies, including the Point No Point Treaty Council,

the Skokomish Tribe, the Port Gamble S'Klallam Tribe, the Jamestown S'Klallam Tribe, and the Lower Elwha S'Klallam Tribe, and the U.S. Fish and Wildlife Service (USFWS). The qualitative habitat assessment presented herein is a summary of extensive field surveys and watershed analyses completed by these and other agencies and the Olympic National Forest. A quantitative comparison of pristine or historical habitat quantity and quality has generally not been possible, though some estimates of lost habitat have been made in well-surveyed reaches, or where old photographs or maps exist.

Fish Stock Status

Fish stock status is assessed in terms of the recent trend in the annual number of spawners (i.e. escapement). Escapement has been estimated for all individual rivers or streams where summer chum salmon (*Oncorhynchus keta*) runs currently exist. In contrast, coho salmon (*O. kisutch*) escapement is estimated for regional aggregates of stream and river systems in WRIA 17 – Quilcene Bay and Dabob Bay, northern Hood Canal, and the eastern Strait of Juan de Fuca. Supplementary information from individual streams, for example counts of adults or redds in certain index reaches, is summarized where such data exist. Relatively little quantitative information exists on the annual return of fall chum salmon and winter steelhead (*O. mykiss*). Almost no information exists about chinook salmon (*O. tshawytscha*) or anadromous or resident cutthroat trout (*O. clarki*). Bull trout (*Salvelinus confluentus*) distribution has not been described in WRIA 17.

In general, stocks of summer chum and coho salmon that originate in WRIA 17 are depressed. In the Big Quilcene River, summer chum salmon returns increased dramatically in the late 1990's, likely as a result of an ambitious supplementation program at the QNFH. Chimacum Creek summer chum salmon were extirpated in the mid-1980's, but the Salmon Creek stock was re-introduced in 1996, with the first adult returns observed in 1999. Summer chum salmon returns to the Little Quilcene River, Snow Creek, and Jimmycomelately Creek are depressed. Coho salmon returns to northern Hood Canal and Dabob/Quilcene bays have shown an increasing trend since the early 1990's. But returns to the individual small streams entering Hood Canal, other than the Big Quilcene and Little Quilcene rivers, range from 10 to 30 annually. Coho salmon escapement to Chimacum Creek has increased slightly since dropping below 50 in the early 1990's. Escapement to Snow Creek and Jimmycomelately Creek has fallen to critically low levels. Coho salmon smolt production in Snow Creek has shown a declining trend for the last 15 years. Outside of Snow Creek, where escapement has ranged between 20 and 80 since 1990, winter steelhead escapement or productivity is not closely monitored. Surveys have counted a few steelhead spawning in the Little Quilcene system, and Tarboo, Thorndyke, and Shine creeks.

Habitat Conditions

The habitat assessment surveys summarized in this assessment concur in the conclusion that, throughout WRIA 17, freshwater and riparian habitat is currently in poor condition (Table ES-3). Spawning habitat quality is compromised by high sediment loading, and in many sub-basins is further affected by unstable channel substrate at high flow. In the lower reaches of streams where summer and fall chum salmon spawn, the banks have been modified in the interest of flood control, and channel complexity reduced to speed runoff. These modifications contribute to substrate instability and scour at high flow. Streams are characterized by low summer flow. Water diversion from the Big Quilcene and Little Quilcene rivers, and disruption of wetlands which would otherwise buffer base flows, exacerbate low flow constraints on rearing juvenile salmonids and spawning summer chum salmon. In all streams rearing habitat quality has been reduced because pool-forming large woody debris (LWD) has been removed or is no longer being recruited from the riparian zone. Development of streamside land for agriculture and residential purposes, and timber harvest has left many reaches without mature coniferous trees that generate stable LWD.

Table ES-3. Summary of Fish Habitat Assessment Data by Sub-Basin

Sub-basin	Stream or River	Reach Assessed	Primary Data Source	Habitat Quality
Big Quilcene	Big Quilcene MS	0.0 – 3.3	Bernthal et al. (1999) BQWAT (1994)	Chum salmon spawning habitat poor – high sediment load, channel instability, low flow Coho salmon rearing habitat fair to poor.
	Penny Creek	0.0 – 7.5	BQWAT (1994)	Inaccessible; potentially good coho salmon rearing habitat.
	Townsend Creek	0.0 – 4.8	BQWAT (1994)	LWD low; fair cutthroat habitat.
	Spencer Creek	0.0 – 2.5	BQWAT (1994)	Spawning habitat poor – high sediment load. Rearing habitat poor – LWD low, pools small and infrequent.
	Marple Creek		BQWAT (1994)	Spawning habitat degraded by sediment load. Rearing poor – low LWD, pools inadequate.
Little Quilcene	Little Quilcene MS	0.0 – 5.2	Bernthal et al. (1999)	Spawning habitat poor – low flow, sediment load high, channel unstable. Rearing habitat poor – low LWD, low channel complexity, few pools.
	Howe Creek	0.0 – 2.8	Bernthal et al. (1999)	Spawning habitat limited. Rearing habitat fair – low LWD, wetlands provide winter habitat. Upper reaches dewatered in summer.
	Ripley Creek	0.0 – 0.7	Bernthal et al. (1999)	Spawning habitat fair. Rearing habitat fair – pools, LWD adequate.
	Leland Creek	To lake	PEI (2000)	Low flow limits access; riparian zone degraded.
	Donovan Creek Trib 17.0116 Trib 17.0018	0.0 – 1.9 0.0 – 1.0 0.0 – 1.8	PNPTC unpub data	Spawning habitat poor – sediment load, high winter flow. Rearing habitat fair – riparian degraded, LWD low, channel unstable.
Dabob Thorndyke	Tarboo Creek Trib 17.0130	0.0 – 7.0 0.0 – 1.1	PNPTC unpub data	Spawning and rearing habitat poor – high sediment load, channel aggraded, low LWD and pool quality.
	Thorndyke Creek Trib 17.0171 Trib 17.0174	0.0 – 6.6 0.0 – 1.2 0.0 – 0.8	PNPTC unpub data	Spawning and rearing habitat good – possible sediment load from upstream logging, low summer flow.
Ludlow	Shine Creek	0.0 – 3.0	PNPTC unpub data	Spawning habitat poor in lower reach – high sediment load. Rearing habitat in upper reach degraded, channelized; wetland offer winter rearing potential.
Chimacum	Chimacum Creek MS East Fork West Fork	Mainstem, East and West Forks	Bahls and Rubin (1996)	Spawning and rearing habitat poor – high sediment load, low channel complexity, LWD absent in valley reach, water quality marginal, low summer flow.
Salmon Snow	Snow Creek	All	SSWAT (1996)	Spawning and rearing habitat poor – high sediment load, poor LWD recruitment potential, few pools, low summer flow, high winter flow.
	Salmon Creek	0.2 – 3.8	Bernthal et al. (1999)	
West Sequim Bay	Jimmycomelately	0.0 – 1.5	McHenry et al. (1996)	Spawning and rearing habitat poor – high sediment load, channel simplified and aggraded.

Cleared areas are usually repopulated naturally with deciduous species, such as red alder, which can contribute to instream LWD, but they tend to decay more quickly and be less stable. Pool frequency and size is further reduced by high sediment loading. In some cases stream channels have been straightened, and side channels and meanders eliminated where, previously, deep, low-velocity pools would have provided suitable rearing habitat. Off channel wetland and beaver ponds, though they still exist in some streams, have been substantially reduced in developed stream corridors, with suitable over-winter rearing habitat reduced as a result. Improperly constructed road culverts partially or completely block access to substantial areas of rearing and spawning, habitat.

Sub-estuaries, at the interface of the stream mouths and Hood Canal and the Strait of Juan de Fuca, provide critical habitat for summer and fall chum salmon that originate in WRIA 17 streams, as well as juvenile chum salmon and chinook salmon that migrate through these highly productive zones. Diking and filling of deltas has reduced the complex web of distributary channels and sloughs that support post-emergent chum salmon fry (Table ES-4).

The most useful habitat surveys have collected an extensive database that quantifies aspects of habitat which are critical to salmonids, (e.g. pool frequency, size, and depth, abundance of LWD in the stream channel and the riparian zone. The relative importance of different aspects, (e.g., the effects of a degraded stream channel vs. a degraded riparian zone) are not usually compared because they are inextricably linked. Most of the raw data collected by these surveys follow a similar protocol, and are therefore suitable for inclusion in regional spatial databases, such as the Salmon Steelhead Habitat Inventory and Assessment Project (SSHIAP).

An inventory of natural and man-made barriers to fish migration is presented, based on data collected by the WDFW. Road culverts are rated as to whether they present complete or partial barriers to migration. The historical and current distribution of the different salmonids in lower order streams in WRIA 17 is not completely described, and the current quality of habitat in many of the upper reaches is only generally characterized. The true potential value of removing any one barrier will ultimately depend on more complete description of these factors.

Table ES-4. Summary of sub-estuarine habitat quality for streams in Watershed Resource Inventory Area 17 (Ames et al. 2000)

Stream or River	Estuarine Habitat Quality
Big Quilcene River	River mouth extended 1700 ft. by aggradation, channelization; 26% of original delta filled or obstructed by dikes.
Little Quilcene River	Dikes isolate mouth from distributary sloughs – 25% of original delta isolated.
Thorndyke Creek	Nearly pristine.
Chimacum Creek	Estuary relatively intact, no dikes, jetties, roads. Some fill area associated with log dump at estuary mouth.
Salmon-Snow Creeks	25% of delta isolated from tidal flow by roads, causeways, railroad grade.
Jimmycomelately Creek	5% of original delta isolated by roads or residential development. Stream mouth aggraded, perched above intertidal; log storage area affects benthic productivity.

Restoration Projects

Over one hundred restoration projects have been completed in WRIA 17 since 1988. The projects have been done by one or more of the following organizations and agencies: Wild Olympic Salmon, Jefferson County Conservations District (JCCD), North Olympic Salmon Coalition, Jefferson Land Trust, WDFW,

Jefferson County Public Works and Port Gamble S'Klallam Tribe. These projects have included land acquisitions, instream habitat restoration, riparian plantings, stream corridor fencing, and culvert barrier replacements. Land acquisition and fencing projects have been designed primarily to prevent livestock from grazing in riparian areas and along stream channels. Instream habitat restoration and riparian planting projects have been primarily designed to restore streams with extensively modified channels, to re-establish more natural channel morphology and native riparian vegetation. Culvert replacement projects have been designed to eliminate salmon passage barriers and to re-establish access to suitable habitat upstream. The majority of restoration projects have been combinations of the types of projects discussed above, such as land acquisition and riparian planting, or culvert replacement and channel restoration. Restoration projects have been common in the Chimacum Creek sub-basin, where significant efforts have been made to fence livestock from the stream channel and restore both instream salmon habitat and riparian vegetation. Subject to final funding approval, fifteen additional restoration projects are planned for construction in the summer of 2000 on WRIA 17 streams. These restoration projects are similar to those previously completed in WRIA 17, and focus on restoring salmon habitat, acquiring land adjacent to the creeks and streams, and eliminating culvert barriers.

As the scope and variety of habitat enhancement projects has increased in recent years, the need to monitor their effectiveness is being emphasized. Standardized protocols and standards for monitoring project effectiveness have not been applied in WRIA 17. Projects should be judged by the degree to which they facilitate the return of self-maintaining structure, function, and natural process to streams and riparian corridors, and estuarine zones.

INSTREAM FLOW

Many streams within the WRIA have theoretical optimum instream flows developed by one or more investigators. Theoretical optimum instream flows were developed using one of two commonly accepted methods: the toe-width method and the Instream Flow Incremental Method (IFIM). These methods are those recommended by Washington State resource agencies to develop theoretical optimum instream flows.

Information is also available from recent toe-width studies, and an IFIM study, to develop theoretical optimum flows for other streams. Fish species considered included chum salmon, coho salmon, and chinook salmon and steelhead trout; lifestage requirements considered included spawning and juvenile rearing. Taken together, there is enough information to develop theoretical optimum instream flows for most of the larger streams in the WRIA.

No streams within the WRIA have instream flows set by the Department of Ecology (Ecology) as administrative rules. Diversions on the Big Quilcene River are, however, managed to comply with a voluntary instream flow arrangement, which restricts diversion during low-flow periods.

DATA INTEGRATION AND SUMMARY

Generally speaking, aspects of water resources, water quality and degraded habitat are not the result of a single or isolated factor. The data integration and synthesis therefore seeks to “bring together” the different elements of the technical assessment to assess the potential inter-relationships between water quality, water quantity, habitat and land-use. The following discussion relates to the data integration on a WRIA-wide basis. Sub-basin chapters presented later in this report present data integration and synthesis for each sub-basin.

The data integration and synthesis approach used in this assessment is designed to present information at a WRIA scale, and then to use the information to help focus additional work at a sub-basin scale.

Ultimately, it is expected that sub-basin assessments will be used to focus and direct activities at a segment or stream reach scale.

Figure ES-2 presents a summary of the data integration and synthesis for WRIA 17. This "concurrent issues" figure was created by overlaying the GIS coverage layers shown in Appendix A. The fisheries habitat layer was developed based on a qualitative analysis of previous habitat assessments conducted in WRIA 17, as described in Chapter 5 and as shown in Figure 5-5. Readers should note that Figure ES-2 is intended to provide an overview of potential concurrent issues, and to serve as reference to compare different elements of the assessment on a WRIA-wide spatial scale. Due to the many data gaps identified in this assessment, Figure ES-2 should be considered preliminary and subject to change as better information becomes available.

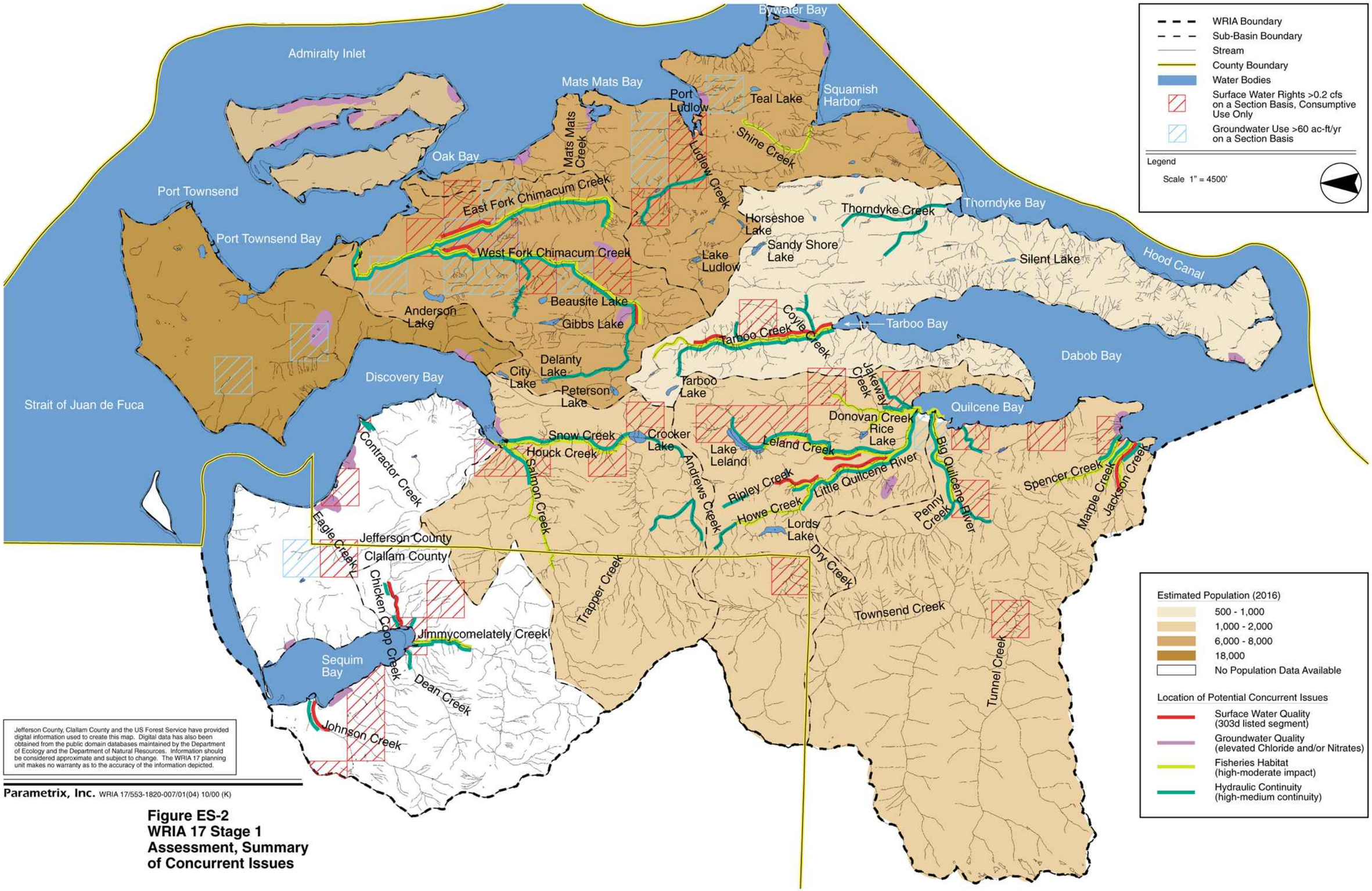
Figure ES-2 does not show locations where existing streamflows are known to not meet previously optimum instream flows for fish habitat. This is intentional and reflects the high degree of uncertainty regarding existing optimum instream flows values. It is well known that surface and groundwater use can influence freshwater, riparian, and nearshore habitat quality through a number of pathways that affect aquatic ecosystem integrity and fish productivity. A fundamental impact pathway can involve the increase in demand for water, which may involve increased withdrawal of groundwater, diversion of surface water, or import of water from out of the local basin. The extent to which increased water withdrawal (particularly groundwater) may affect streamflow, particularly during the late summer and fall when streamflow is usually at critically low levels in WRIA 17 systems, is difficult to predict. The geomorphology underlying the aquifers of WRIA 17 sub-basins, and the factors described which control the connectivity between groundwater and surface flow are currently not well understood. Areas shown as high to moderate-high areas of "relative hydraulic continuity" are provided as an initial first step to depict stream segments where this relative hydraulic continuity has potential to be an issue.

Summary observations from Figure ES-2 and the data integration and synthesis include:

- The Chimacum sub-basin has a number of concurrent issues, with most concentrated in the lower basin near the confluence of the east and west forks of Chimacum Creek. Surface water quality is degraded in this area, and surface water and groundwater use is relatively high. Habitat impacts have been rated as high for both forks of Chimacum Creek, and hydraulic continuity potential has been rated high to moderate-high for most of the Chimacum Creek corridor. Population growth in the Chimacum sub-basin is expected to increase 30 percent by 2016 (1,570 new residents), the third highest growth rate of any sub-basin in WRIA 17.

- The Little Quilcene sub-basin also has water quality, hydraulic continuity, and habitat issues on the majority of the stream corridor. Surface water use is also relatively high in the upper reaches of Leland Creek near Lake Leland. Growth in this sub-basin is expected to be relatively small by 2016, with population estimated to increase from 1,308 in 1996 to 1,797 in 2016.

- Concurrent issues in the Big Quilcene sub-basin are most concentrated in the lower watershed where most habitat impacts have been identified, and groundwater use is highest. By 2016, an estimated 700 residents are projected to be added to this sub-basin. Hydraulic continuity and higher groundwater use in the lower segment of the Big Quilcene River may have potential to increase existing habitat impacts.



Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.

Parametrix, Inc. WRIA 17/553-1820-007/01(04) 10/00 (K)

Figure ES-2
WRIA 17 Stage 1 Assessment, Summary of Concurrent Issues

- The Salmon-Snow Creek sub-basin has habitat impacts and has higher hydraulic continuity potential. Surface water rights are relatively high in lower Salmon and Snow creeks as well, which creates potential to aggravate seasonal low stream baseflows. Growth by 2016 in the Salmon-Snow Basin is estimated at approximately 30 percent, with an estimated 400 new residents.

- The Ludlow sub-basin has habitat impacts in Shine Creek, and supports relatively high groundwater use and surface water rights near Port Ludlow and Ludlow Creek. This higher water use, in combination with the higher hydraulic continuity potential in Ludlow Creek, creates potential stream baseflow issues. This issue should continue to be evaluated since population is expected to more than double in this sub-basin by 2016 (2,882 residents in 1996 increasing to 6,371 residents in 2016).

- Tarboo Creek in the Dabob-Thorndyke sub-basin has surface water quality, habitat and hydraulic continuity as concurrent issues. Although water use is relatively low in this sub-basin, and future population growth is small (180 new residents by 2016) existing land use has had a detrimental impact on stream health.

The data integration approach and above summary listing is not intended to imply rank or priority in the order presented. The data integration and synthesis presented in this assessment should be considered a tool to assist watershed efforts in finding approaches to dealing with water supply needs, declining salmon stocks, degraded water quality, and stream baseflow.

LAND USE, FUTURE GROWTH AND POTENTIAL IMPACTS

Land use in WRIA 17 is primarily forest lands, followed by low-density rural residential, agriculture and urban growth areas. Population growth in WRIA 17 is projected to increase 55 percent between 1996 and 2016, from approximately 25,000 to 38,000. The lack of specific information regarding anticipated future land-use changes associated with this growth make it difficult to predict related potential impacts. However, a general evaluation of the potential relationships between growth and particular land uses, water quality, water quantity, and habitat was performed.

Water Quality

Land use practices have impacted groundwater and surface water quality in many areas of WRIA 17. Agricultural practices, and residential and commercial development have resulted in bacterial contamination of fresh and marine water. Land clearing has removed vegetative cover in riparian zones, and resulted in elevated stream temperatures during warmer periods of the year. Forest practices have also contributed to elevated turbidity and suspended solids levels in WRIA 17 streams. Groundwater quality has also been effected by land-use in WRIA 17, with elevated chloride and nitrate levels observed in some areas. In general, however, the relationship between specific land uses and observed groundwater quality conditions has not been well established.

In the future, development to meet increased residential use in rural areas will most likely utilize individual septic systems, which if improperly sited or constructed, may increase nutrient and coliform loading to surface water and groundwater. Future growth will likely be accompanied by an increase in agricultural activities, both at a commercial and “hobby” scale. Finally, impacts of new groundwater withdrawals (i.e., saltwater intrusion) have potential to increase chloride concentrations in coastal areas.

Water Quantity

Changes in land use may affect the availability of groundwater in WRIA 17 because groundwater is recharged via processes that occur at the land surface. Significant changes to land use could alter the timing of recharge, the magnitude of recharge, and/or its spatial distribution. For WRIA 17, four types of land-use alteration were identified that could potentially affect groundwater recharge, and thus water quantity: (1) impervious surfaces associated with residential development; (2) changes in vegetative cover associated with residential development or agriculture; (3) water management associated with residential development; and (4) changes associated with logging.

Actual data documenting the relationships between land-use change and groundwater availability in WRIA 17 are unavailable. Estimates regarding changes in land-use areas over time were not available at the time of this study, and direct hydrogeologic data useful for comparison (e.g. trends in groundwater levels and/or stream baseflows) were also unavailable. However, a combination of general hydrogeologic understanding, the results of recharge modeling, and a literature review regarding the impacts of impervious surfaces and variations in land cover were used to develop framework to describe the potential impacts of land-use and growth on water quantity. Application of the recharge model to WRIA 17 is intended to provide reasonable estimates of recharge inflows; however, on the local scale, natural variation and parameter uncertainty dictate that recharge estimates be seen as approximate.

Changes in land use or cover can also have a significant effect on the rate and timing of surface water flow in rivers and streams. The types of land cover or land use changes experienced in WRIA17 include conversion of either forest or agricultural land to urban land uses (impervious surfaces); logging of forested lands and replanting with seedlings; and logging of forested lands and conversion to grass or agricultural uses. The effects of those changes are well described in the preceding section on groundwater, which is also relevant to surface water effects. The effect of each change is relative to the amount of land it disturbs, its location in the basin, the soils that underlie the area and the rainfall regime. Hydrologic models can be used to estimate the changes in streamflow resulting in land use changes. Such an effort was not undertaken for this study because of the cost and timeframe to perform this modeling exercise.

On a WRIA-wide basis, population growth over the next 16 years is estimated to increase water use approximately 33 percent over existing conditions. Predicted increases in water demand for each sub-basin based on existing population data is shown in Table ES-5. As shown in Table ES-5, this has potential to result in an approximate 1 to 2 percent increase in recharge used, which could increase the total amount of recharge used from approximately 4 percent under current conditions, to 6 percent in 2016.

Habitat

Most of the major salmonid-bearing stream basins in WRIA 17 have been moderately or highly impacted by land use practices or agricultural and residential development. Development patterns and land-use practices that began over 100 years ago have dramatically altered stream channels, cleared riparian forest and vegetation, and drained or disconnected side channels and wetlands. Development in the floodplains of large streams has necessitated construction of flood control measures, such as straightening channels, clearing them of LWD, construction of dikes, and armoring of banks. In several systems timber harvest and road building in the upper basins, combined with channel simplification and riparian clearing, have increased sediment loading. Aggradation that results in the lower reaches of systems then exacerbates flood risk, which has prompted further flood

Table ES-5. Summary of Population Projection and Distribution, and Potential Impact on Water Demand

WRIA 17 Sub-basin	Year 1996 Pop.	Year 2016 Pop.	Net Pop. Increase	Percent Pop. Increase	Est. Water Use Increase (af/yr)	Current Ground-water Use (af/yr)	Est. Percent GWU Increase (percent)	Estimated Recharge (af/yr)	Current Recharge Used (percent)	Increase in Recharge Used (percent)	Consumptive Increase in GW Use *(af/yr)*
Big Quilcene	1,299	1,943	644	50%	82	322	25%	10,279	3.1%	0.8%	11
Chimacum	5,675	7,284	1,573	28%	200	1,803	11%	18,712	9.6%	1.1%	26
Dabob-Thorndyke	411	596	185	45%	24	96	25%	39,743	0.24%	0.06%	3
Indian-Marrowstone	839	1,015	176	21%	22	287	8%	3,002	9.5%	0.7%	3
Little Quilcene	1,308	1,797	483	37%	62	287	21%	14,652	2.0%	0.4%	8
Ludlow	2,882	6,371	3,489	121%	444	702	63%	21,237	3.3%	2.1%	58
Miller	N/A	N/A	N/A	N/A	N/A	595	N/A	N/A	N/A	N/A	N/A
Quimper (Mixed GW and SW Analysis)	11,293	17,952	6,659	59%	848	670	n/a	8,980	7.5%	n/a	N/A
Quimper (GW only)	11,293	17,952	1,149	10%	146	670	22%	8,980	7.5%	1.6%	19
Salmon-Snow	1,085	1,470	385	35%	49	158	31%	9,461	1.7%	0.5%	6
West Sequim	N/A	N/A	N/A	N/A	N/A	307	N/A	N/A	N/A	N/A	N/A
Totals	**24,792**	**38,392**	**13,600**	**55%**	**1,732**	**5,227**	**33%**	**126,066**	**4.1%**	**1.4%**	

N/A = Not Available

Assumptions: Water use per hookup 250 gpd
Water use per capita 114 gpd
Water use per capita 0.127385 af/yr
Water use returned by septics 87%

control measures. In total, all these changes have dramatically reduced the productivity of fish populations in these systems.

Population increase can potentially influence freshwater, riparian, and nearshore habitat quality through a number of pathways that affect aquatic ecosystem integrity and fish productivity. A fundamental impact pathway involves the increase in demand for water, which may involve increased withdrawal of groundwater, diversion of surface water, import of water from out of the local basin. The extent to which increased groundwater withdrawal may affect streamflow, particularly during the late summer and fall when streamflow is usually at critically low levels in WRIA 17 systems, is difficult to predict. The geomorphology underlying the aquifers of WRIA 17 sub-basins, and the factors described which control the connectivity between groundwater and surface flow are currently not well understood.

As preserving and restoring the integrity of aquatic systems has attained higher priority in the last twenty years, the habitat requirements of fish, and fluvial and biological functions that create and maintain suitable habitat, are becoming better understood. Recovery of salmon populations requires that existing high quality habitat be maintained and protected, and that degraded habitat be allowed to recover. Development patterns and land-use practices in rural areas in WRIA 17 will influence the extent to which habitat recovery occurs. Protection of streamside riparian buffers will be important. Concentrated development will result in increase in impervious surface from which stormwater runoff must be detained, treated, and infiltrated in order to maintain water quality and prevent increasing peak streamflow. Development within floodplains, particularly those parcels near stream mouths, and removing or setting back dikes may contribute to long-term salmon recovery objectives. Potential impacts of growth and new development will also depend in part on protection of critical areas which currently contain high quality stream habitat or have high potential for restoration.

Instream Flow

Impacts to instream flow due to future land-use and growth cannot be predicted due to the uncertainty regarding specific location of growth, source of future water supply, and the accuracy of theoretical optimum instream flows. In general, it would be anticipated that increased water withdrawals would have potential to decrease instream flows, particularly in areas with higher hydraulic continuity.

DATA QUALITY, GAPS AND LIMITATIONS

Water Quality

Surface Water Quality

In general, the quality and quantity of water quality data is limited in both spatial coverage and temporal extent. The majority of water quality data are greater than five years old, with a significant amount of data approximately 10 years of age. Existing water quality data are also typically limited in spatial extent, parameters sampled, and frequency of sample collection. Ambient water quality conditions for parameters other than FC and temperature are generally limited. These limitations generally result in an inability to analyze for trends over longer periods of time.

Non-point source data for WRIA 17 are typically qualitative and lacks specific location information. The location of point and non-point sources and changes over time is difficult to determine over much of the WRIA due to a general lack of detail on source locations in previous reports and studies. Non-point source mapping in this report generally relies on the limited source mapping information contained in previous studies. Potential forestry related impacts, such as erosion or temperature, are generally

discussed in several WRIA 17 reports, but not specifically identified or located. For these reasons, the specific location and magnitude of non-point sources are generally not well characterized throughout the WRIA.

Groundwater Quality

General data gaps are predominantly focused on problems with chloride and saltwater intrusion, however, investigation of clustered area(s) of elevated nitrate may also be warranted. Data on coliform bacteria, iron and manganese, and the potential causes of elevated chloride concentrations in problem areas are a groundwater quality data gap. Future groundwater quality assessments should consider additional hydrogeologic interpretation of the local groundwater flow systems to identify the risks of intrusion for different water-bearing zones and help distinguish between saltwater intrusion and natural sources of chloride "trapped" in aquifer materials.

Water Quantity

Hydrogeologic characterization is relatively poor for many areas in the WRIA. Hydraulic continuity between localized and principal aquifers has generally not been defined based on hydrogeologic and stream baseflow data. Hydrogeologic cross-sections are generally unavailable at the level of detail that portrays potential hydraulic connections between aquifers and streams, groundwater level maps are unavailable to portray discharge or recharge to/from streams, and baseflow seepage studies have not been performed to identify gaining and losing stream reaches.

Well locations are well defined for recent well installations, but poorly defined for wells drilled prior to 1996. Wellhead elevations are poorly defined based on well locations and topographic data. Water budgets are typically missing many components associated with the groundwater flow system. Stream baseflow and springflow data can be used to better define water budgets for groundwater.

Groundwater claims are significant in magnitude relative to confirmed groundwater rights. The degree to which groundwater claims are actually put to use, however, is largely unknown. Additional data are also required to support better estimation of groundwater use from irrigation. For the entire WRIA, a large portion of surface water use is not known, and for sub-basins other than the Big Quilcene and Little Quilcene River, there is not sufficient information on actual water uses to accurately portray the amount of surface water that may be used.

A better understanding of the relationships between land cover, runoff characteristics, and associated groundwater recharge *specific to the development densities in WRIA 17* would be useful for understanding the degree to which changes in land cover affect groundwater recharge. Applicable parameters are generally available for densely developed areas, but less so for rural residential areas.

An additional potentially significant data gap is the lack of stream flow data for many WRIA 17 streams. Historic stream flow data were available only for the Big Quilcene and Little Quilcene River, Chimacum Creek and Snow Creek. Obtaining additional surface water data through installation of stream gaging stations is recommended. The location of the stations may need to be prioritized because of the cost of installation and maintenance of the stations.

Habitat

In general, stream channel and riparian zone habitat in WRIA 17 streams that support populations of anadromous salmonids has been thoroughly assessed. Several protocols have been utilized in this region, each with a particular purpose, and differing slightly in methodology. These include the Timber, Fish and

Wildlife (TFW) protocol (Schuett-Hames et al. 1994), watershed analysis, and the Ecosystem Diagnosis and Treatment (PNPTC 1997 unpublished data). The TFW protocol was applied to the Big Quilcene River, Little Quilcene River and certain tributaries, and Salmon Creek (Bernthal et al. 1999) as part of a larger study of the Hood Canal and Strait of Juan de Fuca region. Bahls and Rubin (1996) completed an exhaustive assessment of historical and current habitat quantity and quality in the Chimacum Creek watershed, expanding on the TFW protocol. Watershed analyses have been completed for the Big Quilcene drainage, including several tributaries, and for the Snow - Salmon system.

The status of fish stocks is described primarily in terms of the recent trend in spawning escapement. With the exception of Snow Creek, where a WDFW research facility provides estimates of the productivity of chum salmon, coho salmon, and steelhead, quantitative estimates of freshwater survival or juvenile salmonid abundance, do not exist for WRIA 17 streams.

The maps in this assessment show the distribution of the various species of salmonids in those streams for which recent habitat assessments and spawning surveys, which were reviewed in this report, are available. In most streams, surveys have focused on the distribution of chum salmon and coho salmon, steelhead, and cutthroat trout. Other species, such as chinook salmon, pink (*Oncorhynchus gorbuscha*), and sockeye (*O. nerka*) salmon, which may regularly stray into WRIA 17 streams, but do not comprise self-sustaining populations, are not mapped in this report. Spawning surveys have contributed significant information on the current utilization of habitat by adult fish, but there are few comprehensive assessments of the distribution of rearing juvenile coho salmon, steelhead, and cutthroat trout. Comprehensive sampling of the Chimacum Creek system (Bahls and Rubin 1996) has provided an exception to this generality.

Other information and databases, such as the Washington Department of Natural Resources (DNR) Streamnet, contain information about fish distribution in WRIA 17 streams for which we found no recent assessments. The distribution of species in Streamnet, in some cases, conflicts with the more recent survey information. In mapping a subset of what is believed to be accurate information on fish distribution, this report recognizes that salmonids are present in many other unsurveyed streams. The value of habitat in these other streams should not be undervalued due to lack of recent information. In many small streams in Hood Canal, outside of WRIA 17, comprehensive surveys have extended the known range for rearing juvenile coho salmon and steelhead (Bahls and Ereth 1994).

Data on fish habitat for the small streams in WRIA17 are limited. Many small unnamed streams have potential to support anadromous salmonids as well as resident cutthroat and rainbow trout. The cumulative importance of these small streams should be considered. Cataloging of these streams for potential fish presence and habitat would help to provide a more complete understanding of fish distribution.

Instream Flow

Taken together, there is enough information to develop theoretical optimum instream flows for most of the larger streams and rivers in WRIA 17. Two exceptions are Snow Creek and Salmon Creek, where consideration should be given to the collection of additional data, either using the toe-width method or the IFIM method. A detailed assessment of the data quality and assumptions used for the existing theoretical optimum instream flows was not performed as part of this report.

FUTURE WORK

Future work will include developing recommendations for Stage 2 of the Technical Assessment, and implementation of Stage 2 data gathering study activities.

1. INTRODUCTION AND STUDY AREA DESCRIPTION

This Stage 1 Technical Assessment summarizes information for the WRIA 17 area and represents the most current compilation and review of existing water quality, water resource, fisheries habitat and instream flow data for the area. This Stage 1 Technical Assessment represents the first step in the technical review and analysis of potential water quality, water resource and fisheries habitat in WRIA 17. As such, it is not designed or intended to provide a complete analysis and or summary of the full array of potential water related issues in the WRIA. This Stage 1 assessment will be followed by subsequent stages of assessment, and eventual preparation of a watershed plan.

This Stage 1 Technical Assessment has been initiated by the WRIA 17 Planning Unit, which is comprised of Jefferson and Clallam counties, the City of Port Townsend, affected tribes, special purpose districts, state agencies, public non-profit organizations, and private industry. The scope of this assessment has been established by the Planning Unit, consistent with the requirements of the Watershed Management Act (RCW 90.82/ESHB 2514). The assessment has been funded in part by the Washington Department of Ecology.

1.1 STAGE 1 TECHNICAL ASSESSMENT PURPOSE AND SCOPE

The general purpose of Stage 1 of the Technical Assessment is to summarize existing watershed information, assess potential growth impacts, identify additional data needs and prepare a WRIA 17 Stage 1 Technical Assessment report. This Stage 1 Technical Assessment summarizes the current status of water quantity, water quality, habitat, and in-stream flow for each sub-basin within the watershed. The Stage 1 Technical Assessment also includes analysis of potential future growth impacts, an integrated analysis of water quantity, water quality and habitat components; and identifies potential data gaps and limitations.

The Stage 1 assessment has been prepared in increments. During the February – August 2000 period separate draft Data Summaries were prepared for each of the following technical elements of the Stage 1 Assessment:

- *Surface and Groundwater Quality Data Summaries* that identified water quality conditions/trends, and known specific point and non-point pollution sources for groundwater and both fresh and marine water.

- *Habitat Assessment Data Summary* that shows by sub-basin the existing and historic habitat areas, location of restoration activities, limiting factors, and status of fish populations.

- *Water Quantity Data Summary* that describes water allocation and use, estimates surface and groundwater quantities and trends, and evaluates effects of land use practices on water quantity.

- *In-Stream Flow Data Summary* that compiles and summarizes existing in-stream flow, regulations, theoretical optimum instream flows and data for the watershed.

The purpose of these draft data summaries was to review and summarize available information. Each of the drafts was reviewed by the WRIA 17 Planning Unit and Technical Committee, with specific technical comments generated for each separate data summary report. Comments were addressed, and the data summaries were updated. This draft Stage 1 Technical Assessment report presents the compilation of these data summaries, as well as additional information on preliminary water budget and data synthesis and integration.

This report recognizes that additional published and unpublished data sources exist for areas throughout WRIA 17. Water purveyors, County and Tribal offices, and consultants are just a few of the organizations that may have data that was not identified and incorporated into this assessment but which may need to be considered in future stages and phases of the WRIA 17 assessment and planning process.

1.2 FUTURE WORK

It is expected that the Stage 1 Technical Assessment for WRIA 17 report will be approved by the WRIA 17 Planning Unit. Following approval of the Stage 1 Assessment, recommendations will be developed for Stage 2 of the Technical Assessment. It should be noted that Clallam County submitted additional information to the Planning Unit after the draft Stage 1 Assessment was completed. It is expected that this information will be incorporated into future data summaries and technical assessments.

1.3 WRIA 17 STUDY AREA GENERAL DESCRIPTION

The WRIA 17 area covers approximately 401,000 acres and includes portions of Jefferson and Clallam County (Figure 1-1). The WRIA is located on the northwest portion of the Puget Lowlands in Puget Sound near the confluence of Admirality Inlet and Hood Canal. Major physical features of the WRIA 17 area include portions of Hood Canal, the Strait of Juan de Fuca, and the northeast flank of the Olympic Mountains. The WRIA has a population of approximately 23,800 people with the primary population center of Port Townsend.

The WRIA 17 area consists of the following 10 primary sub-basins (also refer to Figure ES-1):

Big Quilcene	Little Quilcene	Dabob/Thorndyke
Salmon-Snow	Chimacum	Ludlow
Quimper	West Sequim Bay	Indian/Marrowstone
Miller		

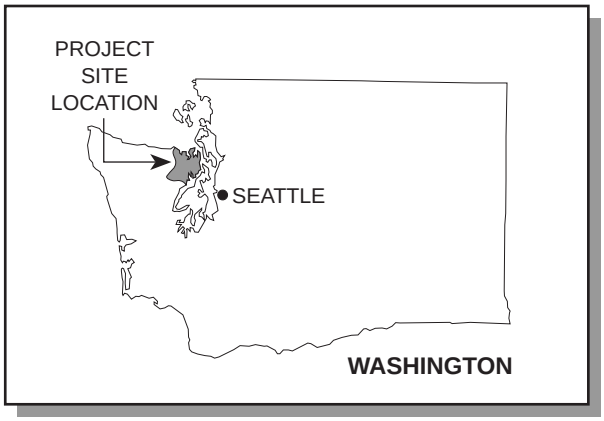
Data for each of these sub-basins are presented in Chapters 8 through 17 of this report.

1.4 SUMMARY OF LAND USE VARIATIONS AND GROWTH PROJECTIONS

This section provides a summary of land-use and project population growth for the WRIA 17 area. Readers should refer to specific technical element and sub-basin chapters for discussion and analysis of potential impacts of land-use and growth.

1.4.1 Summary of Land Use in WRIA 17

The Jefferson County and Clallam County Comprehensive Plans establish land use zones and land use patterns that influence development potential in WRIA 17. Existing land use in WRIA 17 is shown in Exhibit 1. Current generalized land use data supplied by Jefferson County (2000) and Clallam County GIS are presented in Table 1-1.



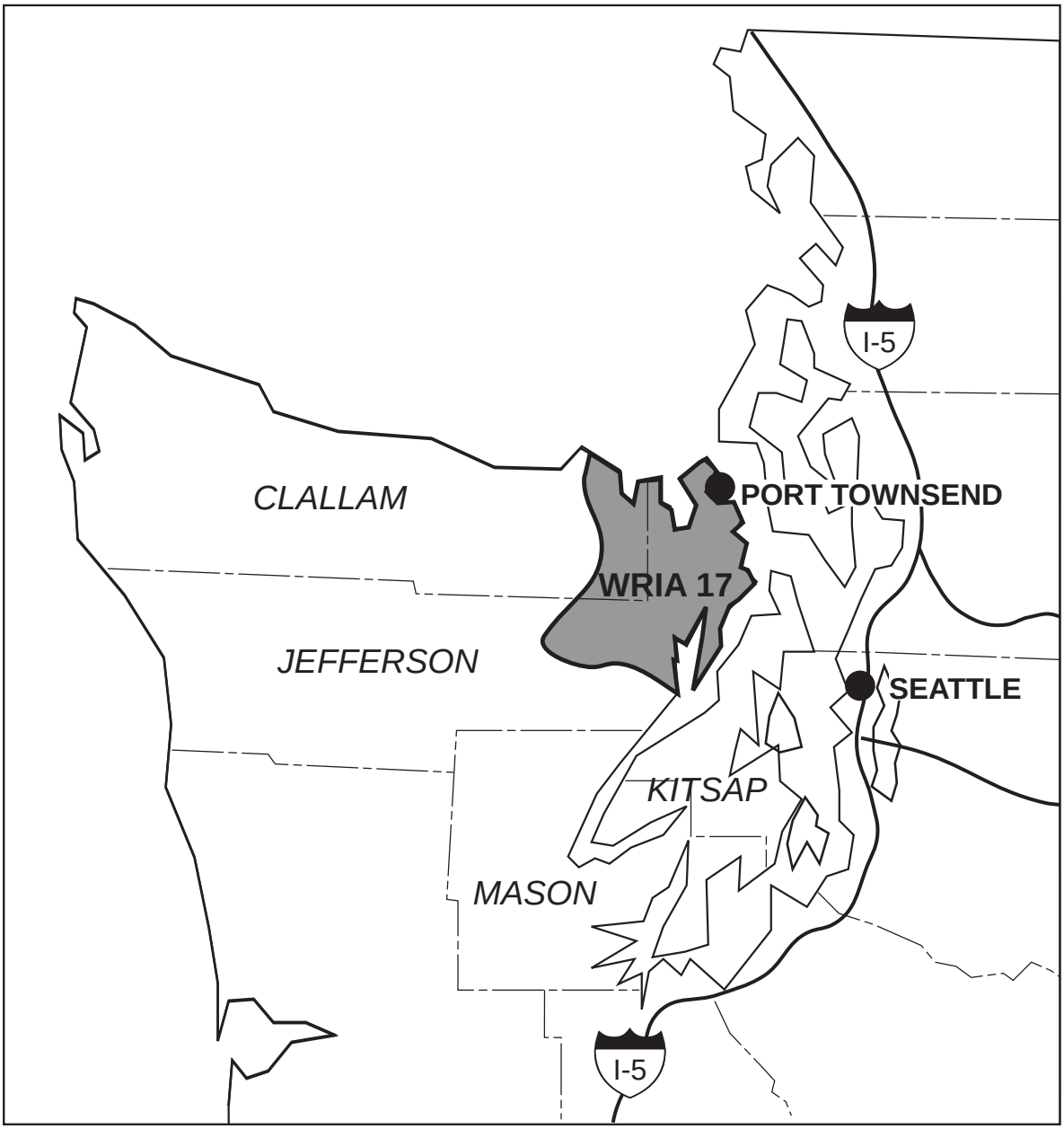


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Figure 1-1
WRIA 17 Location and Vicinity

Table 1-1. Summary of Generalized Land Use (in acres) by Sub-Basin

Sub-Basin	Parks and Open Space	Forestry (Nat. For., Comm., and Inhold)	Rural Residential (1:5, 1:10, 1:20)	Agriculture	Comm. and Ind.	UGA	Other	Totals
Big Quilcene	1,133	44,092	2,703	109	70	0	784	**48,891**
Little Quilcene	16	18,096	6,147	383	51	0	592	**25,285**
Dabob-Thorndyke	3	24,254	7,851	292	0	0	1,431	**33,831**
Ludlow	587	12,300	9,963	122	37	0	1,279	**24,288**
Chimacum	719	8,670	9,141	3,032	87	0	1,002	**22,651**
Salmon - Snow	0	27,064	1,733	410	10	0	994	**30,211**
West Sequim	82	15,765	7,189	0	18	748	28	**23,830**
Miller	82	1,036	11,186	0	61	564	361	**13,290**
Quimper	125	1,803	10,673	0	827	3,861	850	**18,139**
Indian-Marrowstone	768	0	2,907	0	0	0	3,049	**6,724**
Totals	**3,515**	**153,080**	**69,493**	**4,348**	**1,161**	**5,173**	**10,370**	**247,140**

Source: Jefferson County (2000), and Clallam County GIS. Commercial land use includes commercially zoned lands, rural village lands, and rural crossroads, as defined in the Comprehensive Plan. Rural residential lands are the sum of the zones including 1 dwelling unit per 5 acres, 1 dwelling unit per 10 acres, and 1 dwelling unit per 20 acre. Other lands include roads and right of way, tidelands, military reservations and tribal lands.

Land use in each sub-basin is described in each specific sub-basin chapter. Acreage for Jefferson County is based on data provided by Jefferson County, while acreage for Clallam County were calculated based on approved zoning. Jefferson and/or Clallam County may approve future zoning changes through a defined Comprehensive Plan amendment process.

1.4.2 Summary of Population and Potential Growth in WRIA 17

The 1996 "base year" population estimate for Jefferson County has been identified as 25,792 residents (Jefferson County 1998). Jefferson County's population is projected to grow by approximately 13,600 people in the period up to 2016 for an estimated total of 39,392 residents. The population has been distributed consistent with the Growth Management Act with the majority of the growth directed toward the designated Urban Growth Area of Port Townsend, and the remaining population has been allocated to various communities and rural areas throughout the unincorporated areas of the County, consistent with the provisions of the Growth Management Act (Jefferson County 1998). About 40 percent of the population increase is expected to occur in the urban growth area of Port Townsend, and another 20 percent of the increase is projected for the Port Ludlow Master Planned Resort. The remaining portions of Eastern Jefferson County are projected to have a population increase of a total of about 5,200 people over the next twenty years.

Population and growth data were not available for the portion of WRIA 17 located in Clallam County. Most of the Salmon Creek watershed and a large portion of Snow Creek and Little Quilcene River watersheds are located in Clallam County. However, much of the upper reaches of these watersheds are in the Olympic National Forest, and development activities are concentrated in the lower reaches of the watershed, located in Jefferson County (Jefferson County 2000).

Table 1-2 summarized the existing estimated populations for the Jefferson County portion of WRIA 17 as well as the projected population for the 1996-2016 planning horizon. This table was developed by

applying population projections for Local Panning Areas (LPAs) presented in the Jefferson County Comprehensive Plan to WRIA 17 sub-basin boundaries. In general, LPA boundaries coincided with sub-basin boundaries sufficiently to allow application of Jefferson County LPA population data to WRIA sub-basins. Potential sub-basin population should however be considered estimates due to the potential variability associated with differences between LPA boundaries and sub-basin boundaries, as well as variability associated with actual population distribution and zoning.

Table 1-2. WRIA 17 20-Year Population Projection and Distribution

WRIA 17 Sub-Basin Population Projection and Distribution	Estimated Population 1996	Estimated Population 2016	Net Increase
Quimper Peninsula (including Port Townsend)	11,293	17,952	6,659
Ludlow	2,882	6,371	3,489
Chimacum (includes Tri-Area)	5,675	7,284	1,573
Big Quilcene	1,299	1,943	644
Little Quilcene	1,308	1,797	483
Salmon-Snow	1,085	1,470	385
Dabob-Thorndyke	411	596	185
Marrowstone Island	839	1,015	176
West Sequim	N/A	N/A	N/A
Miller	N/A	N/A	N/A
Totals	**24,792**	**38,392**	**13,600**

N/A = Population data Not Available

Source: Jefferson County Comprehensive Plan (1998).

2. PRECIPITATION ANALYSIS

2.1 EXISTING PRECIPITATION DATA

Several data sources were used to obtain precipitation data for WRIA 17, including the Western Regional Climate Center (WRCC) and the Natural Resources Conservation Service (NRCS). Each of these data sources is discussed in more detail below.

2.1.1 Western Regional Climate Center

The National Oceanic and Atmospheric Administration's National Weather Service (NOAA/NWS) administers the Western Regional Climate Center. The National Climatic Data Center (NCDC) of the National Environmental Satellite, Data, and Information Service (NESDIS) provides oversight. The WRCC supports a three-tiered national climate services support program - the partners include the National Climatic Data Center, the Regional Climate Centers, and the State Climate Offices. Databases of the station data inventory listings for NOAA/NWS are posted to the WRCC web site at the following URL: http://www.wrcc.sage.dri.edu/index.html. The National Climate Data Center's Climate Data NCDC hourly precipitation are available on CD-ROM at the University of Washington library network or can be purchased via their web page: http://www.ncdc.noaa.gov/.

There are five active climate stations in WRIA 17 that are administered by NOAA/NWS. The locations of those stations are shown on Exhibit 2 (Appendix A). There are two other climate stations that were discontinued. Both of those stations were located in the Port Townsend area. Descriptions of those stations are listed in Table 2-1. Data collection for climate stations in WRIA 17 began in 1948.

In addition to reviewing data from stations within WRIA 17, a reference station to compare trends in precipitation was selected from Orcas Island. This Station, OLGA 2, provides a longer time series of data, dating back to 1891, in a geographically and climatologically similar location to WRIA 17. Data from two stations in Sequim, Sequim and Sequim 2E, were used in the analysis of the spatial distribution of precipitation in WRIA 17. Those Stations are located just west of WRIA 17. A description of those stations is listed in Table 2-2.

2.1.2 Natural Resources Conservation Service

The NRCS operates a SNOTEL site on Mount Crag, which is located between the Big Quilcene River watershed and the neighboring Dosewallips River watershed. This site remotely collects and transmits hydrologic data via satellite. The SNOTEL site has been operational since 1990. Data collected at that station are available through the NRCS web site at the following URL:
http://www.wcc.nrcs.usda.gov/water/w data.html.

2.1.3 Other Data Sources

Another organization that collects precipitation data in WRIA 17 is the SchoolNet network of precipitation stations operated in conjunction with King 5 News. Precipitation stations have been established at Chimacum Elementary and Blue Heron Middle Schools. Other precipitation data may be available from individuals or community groups. A search for additional data was not performed for this assessment as the data available from the NWS was thought to be sufficient to characterize the spatial distribution of precipitation in WRIA 17.

Table 2-1. Available Climate Records within WRIA 17

Agency	Station	Name/Location	Data Type	Period of Record	Sub-basin	Average Annual Precipitation (inches)
NWS	451414	Chimacum 4S	Climate	1948 - Present	Chimacum	30.1
NWS	456678	Port Townsend	Climate	1948- Present	Quimper	19.5
NWS	456846	Quilcene 2 SW	Climate	1948 - Present	Big Quilcene	55.8
NWS	456851	Quilcene 5 SW	Climate	1948 - Present	Big Quilcene	n/a
NWS	456856	Quilcene Ranger Station	Climate	1953 - Present	Big Quilcene	n/a
NWS	456688	Port Townsend 2	Climate	Unknown - 1969	Quimper	n/a
NWS	456693	Port Townsend 6 SSW	Climate	1970 - 1974	Quimper	n/a
NRCS	450022	Mount Crag SNOTEL	Climate	1990 – Present	Big Quilcene	80.7
City of Port Townsend	Wastewater Treatment Plant	Port Townsend	Climate	1993 – Present	Quimper	n/a

Table 2-2. Other Climate Stations Used in Study

Agency	Station	Name/Location	Data Type	Period of Record	Average Annual Precipitation (inches)
NWS	457538	Sequim	Climate	1948 - 1980	16.7
NWS	457544	Sequim 2E	Climate	1980- Present	16.5
NWS	456096	Olga 2	Climate	1891 - Present	28.9

2.2 SPATIAL DISTRIBUTION OF PRECIPITATION

Precipitation over WRIA 17 ranges from 15 to 20 inches/year in Port Townsend and the northern Miller Peninsula to as much as 70 to 80 inches/year along the foothills of the eastern Olympic Mountains. Higher values occur at higher elevations in the mountains, but data are generally unavailable except for the 10-year record at the Mt. Crag Snotel gage. For the purposes of this study, an isohyetal map was prepared for the lower-elevation portions of the WRIA (Exhibit 2 – Appendix A). The pattern of average annual precipitation on the isohyetal map is largely derived from a previous statewide map developed by the U.S. Weather Bureau (USWB) in 1965. The USWB map is based on historic data from 1930 to 1960, and employed empirical adjustments to predict precipitation in mountainous areas where data were unavailable. For the purposes of this study, isohyetal contours from the statewide map were adjusted locally based on comparisons with period-of-record averages for stations at Quilcene, Chimacum, Port Townsend, and Sequim (Tables 2-1 and 2-2).

The geographic distribution of precipitation is a significant controlling factor in the variation of groundwater recharge and surface water runoff across the WRIA. The potential for recharge and runoff increases with increasing precipitation. Factors such as land cover, soil properties, surficial geology, and the timing of freeze/thaw, control how the available precipitation is distributed between recharge and runoff. In either case, the annual quantity and seasonal timing of recharge are key influences on groundwater and surface water availability. Recharge and surface water runoff are discussed in later sections of this assessment.

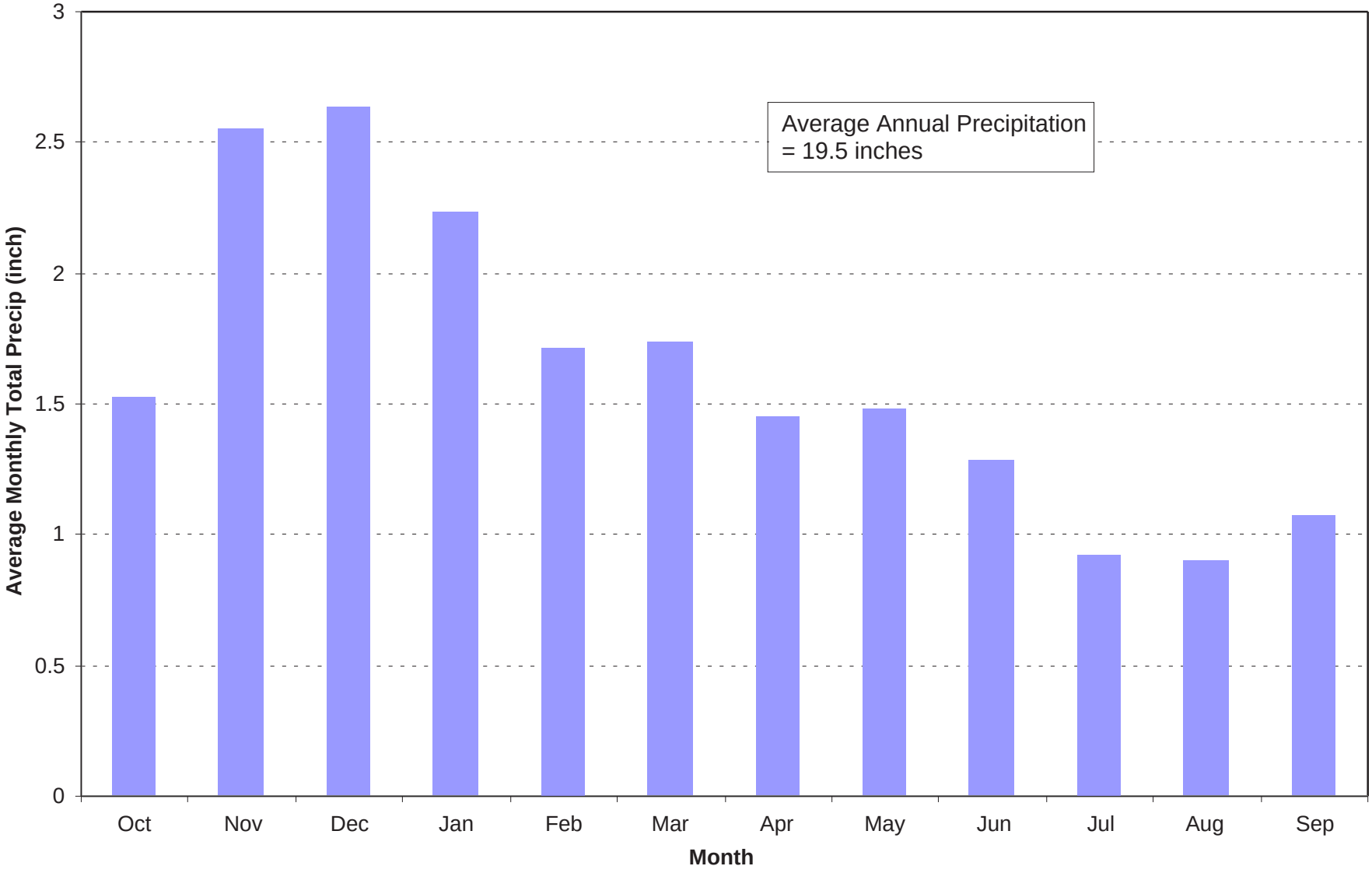
2.3 VARIATIONS AND TRENDS IN PRECIPITATION OVER TIME

Precipitation varies both on a seasonal and on a long-term scale. On a seasonal time scale, WRIA 17 typically experiences a “wet season” between the months of November and May, and a dry season during

the intervening summer and autumn months. Figures 2-1 through 2-4 show monthly average precipitation totals for the Port Townsend, Chimacum, Quilcene 2 SW and Mt. Crag gages. The graph for the Mt. Crag gage also shows the quantity of accumulated snowpack measured in inches of water (called Snow Water Equivalent). Figure 2-5 summarizes the seasonal variability of precipitation at four gages in the vicinity of WRIA 17. For each month, precipitation is expressed as a percentage of the annual total. The figure shows similar seasonal trends among all four gages, with over 70 percent of the total precipitation falling between the months of November and May. Along the eastern edge of the Olympics at Quilcene, a higher percentage of the total annual precipitation falls during the winter months. The seasonal variation between wet and dry seasons however, is only slightly less pronounced at the other three gages. The monthly precipitation percentages shown in Figure 2-5 were used as input for the recharge analysis discussed in Chapter 4.

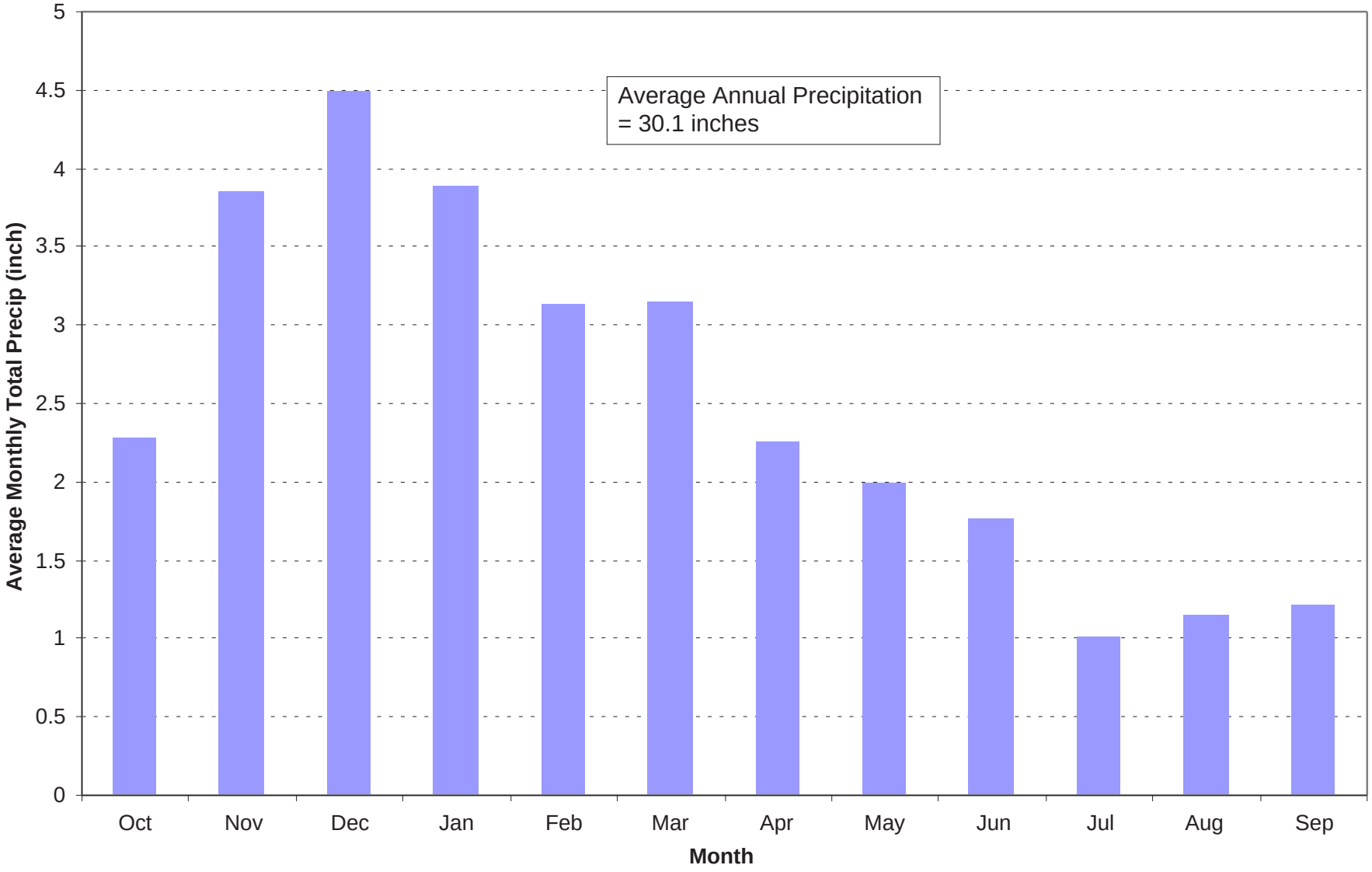
Figures 2-6 through 2-9 illustrate the variability of precipitation by graphing low, median and high values of monthly precipitation values for the four precipitation stations. The low value of precipitation is defined as the precipitation values that occur once every 10 years (exceeded 90 percent of the time). The median values are those that are exceeded 50 percent of the time while the high values are those that are exceeded only 10 percent of the time. The graphs show the wide range of precipitation that can occur between dry, normal and wet months. For example, the difference between the amount of precipitation at Quilcene in January for a dry month is about 1.5 inches, while for a wet month the amount is about 15 inches, or about 10 times the amount that occurs during a dry month. The amount of precipitation directly affects the amount of runoff that occurs in that month or following months.

A review of historical trends in precipitation was performed to analyze the variation of annual precipitation over time. This trend analysis is useful to correlate to trends in streamflow, aquifer water levels, and other hydrologic parameters when sufficient data are available for such correlations. Figure 2-10 presents a graph of annual precipitation totals for the Chimacum, Port Townsend, Quilcene 2 SW and Olga 2 SE stations. The three stations in WRIA 17 have data from the late 1940's while the Olga station has data to 1891. The trends in precipitation between the four stations match well, showing increasing and decreasing trends during the same time periods. The only exception is in the early 1970's, when the trend at the Port Townsend gage was decreasing while the trend at the other gages was fairly static. The graph illustrates the timing and duration of dry periods that have occurred in the WRIA. For example, an extended period of below average precipitation occurred in the 1985 to 1994 time period, while a period of above average precipitation has occurred since 1994.



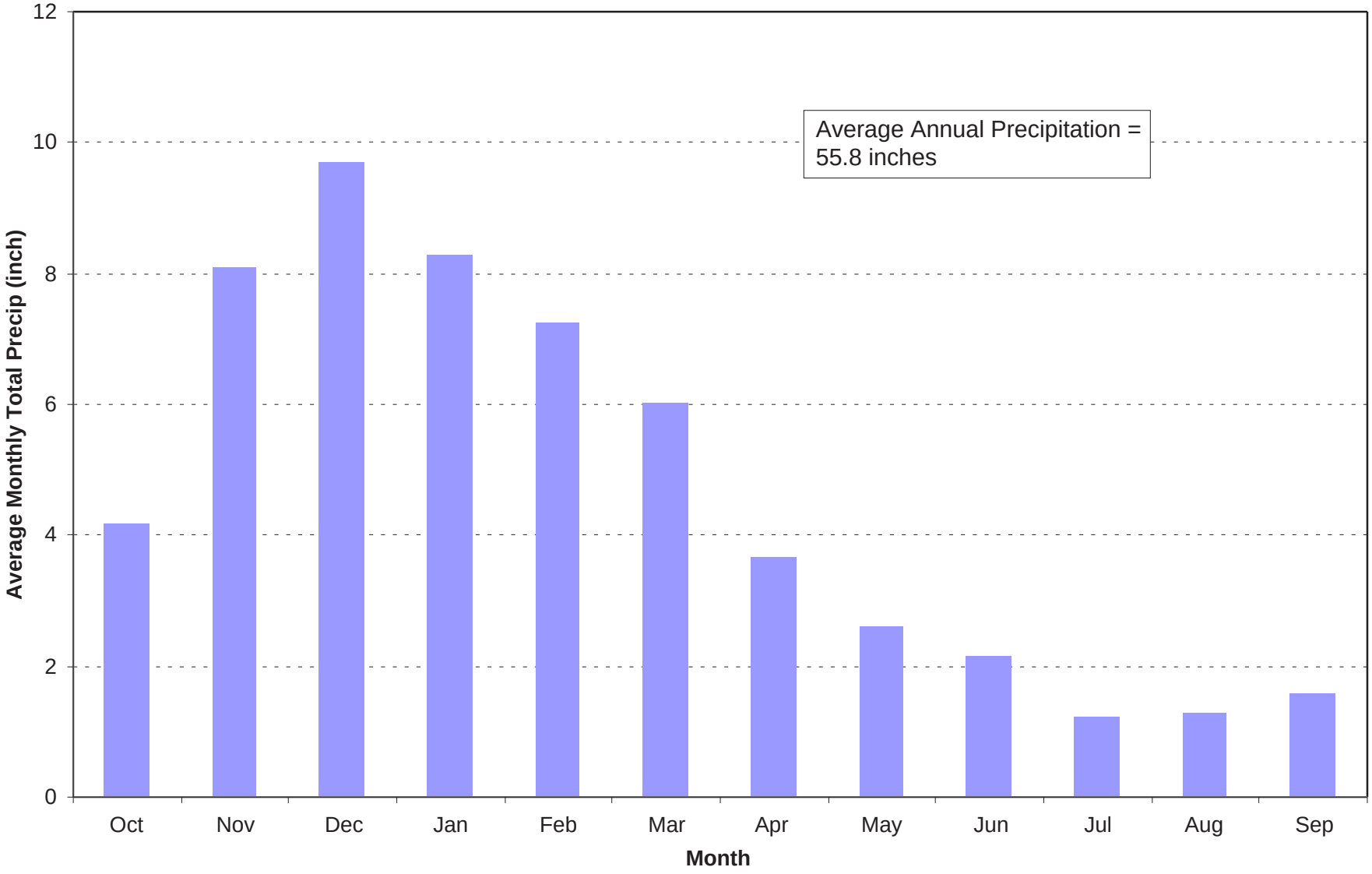
Source: NOAA National Weather Service

Figure 2-1
Monthly Average Precipitation
Port Townsend
Period of Record 1948-1999



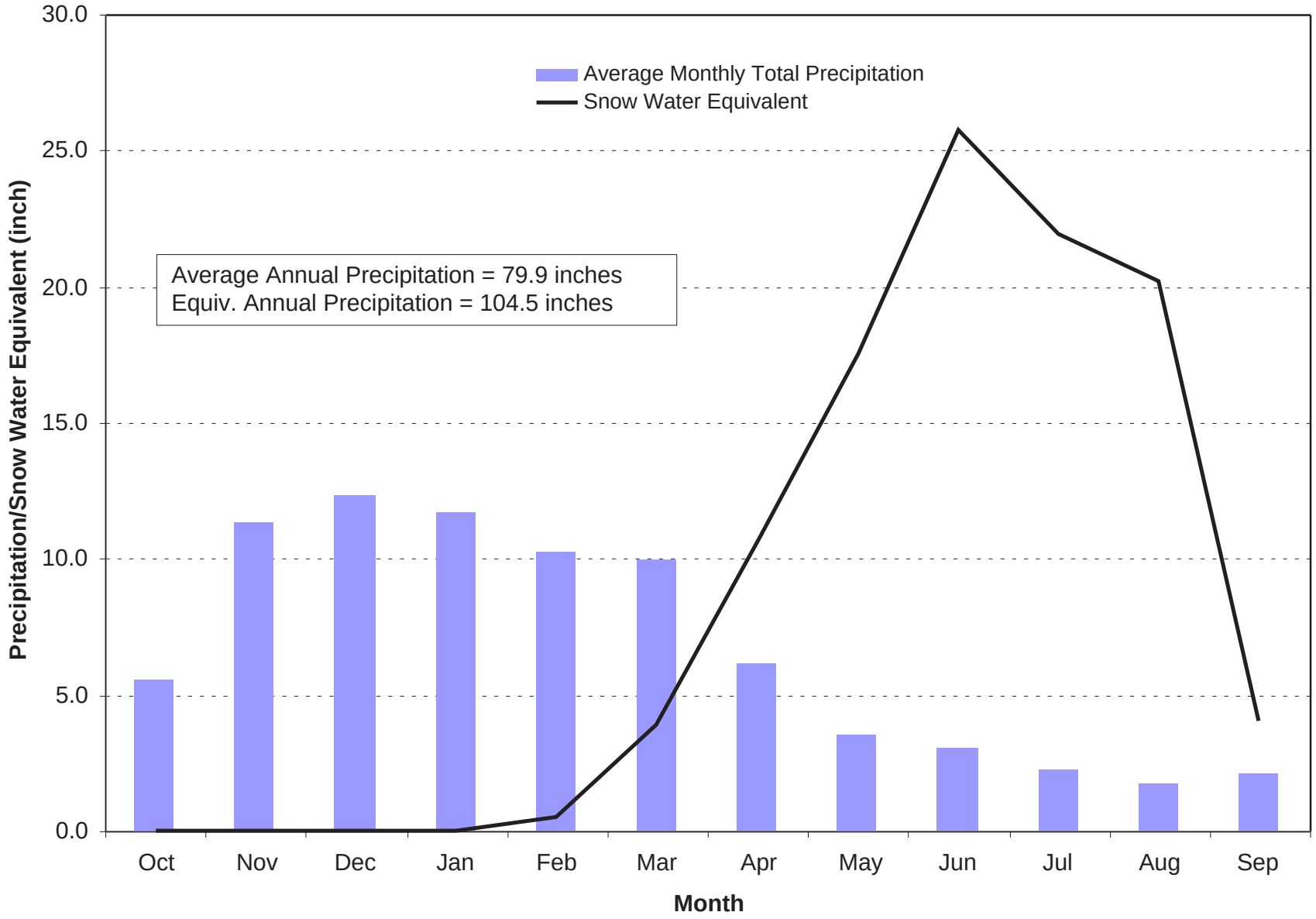
Source: NOAA National Weather Service

Figure 2-2
Monthly Average Precipitation
Chimacum
Period of Record 1948-1999



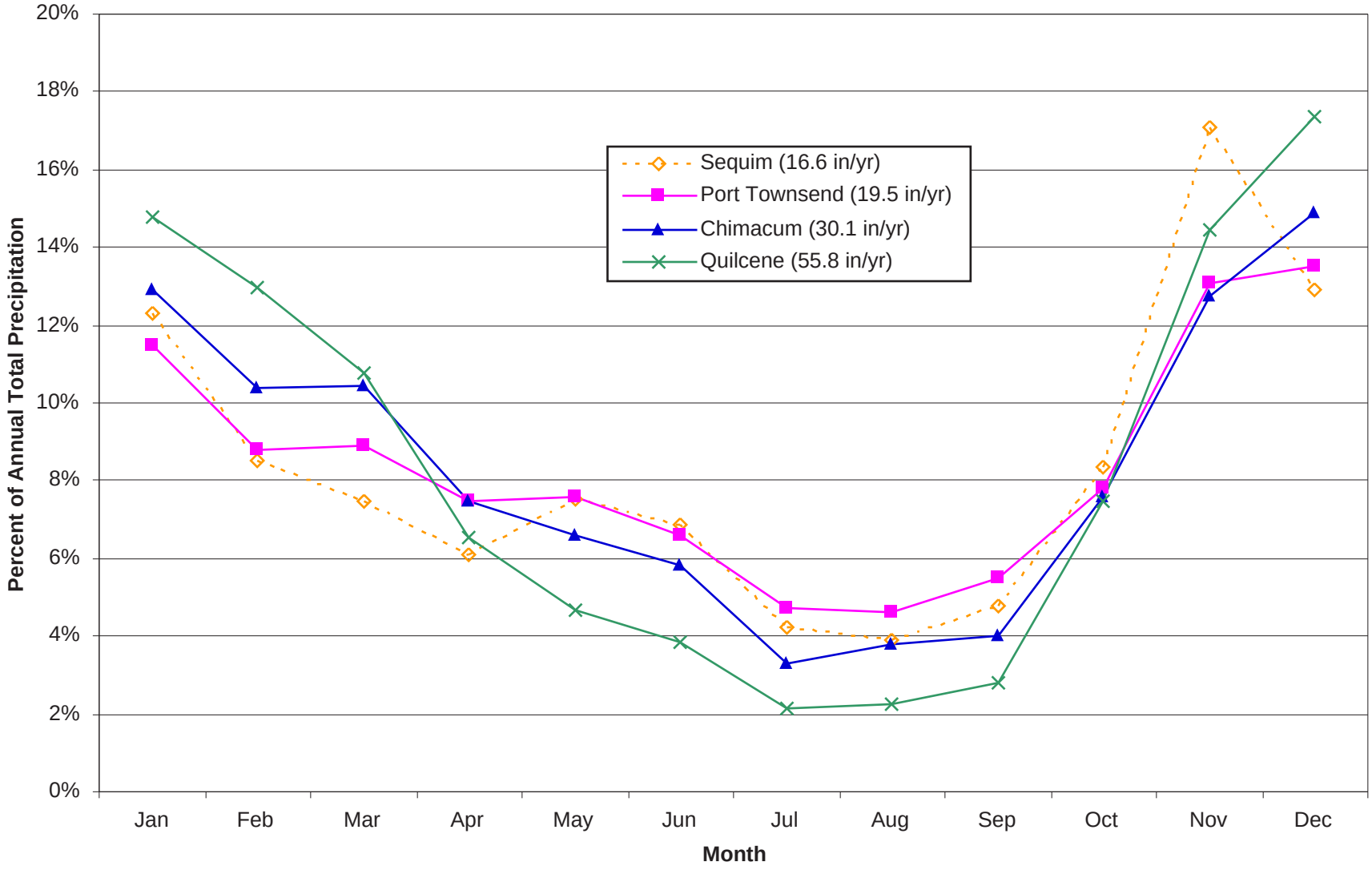
Source: NOAA National Weather Service

Figure 2-3
Monthly Average Precipitation from the Quilcene 2 SW Gage Period of Record 1948-1999



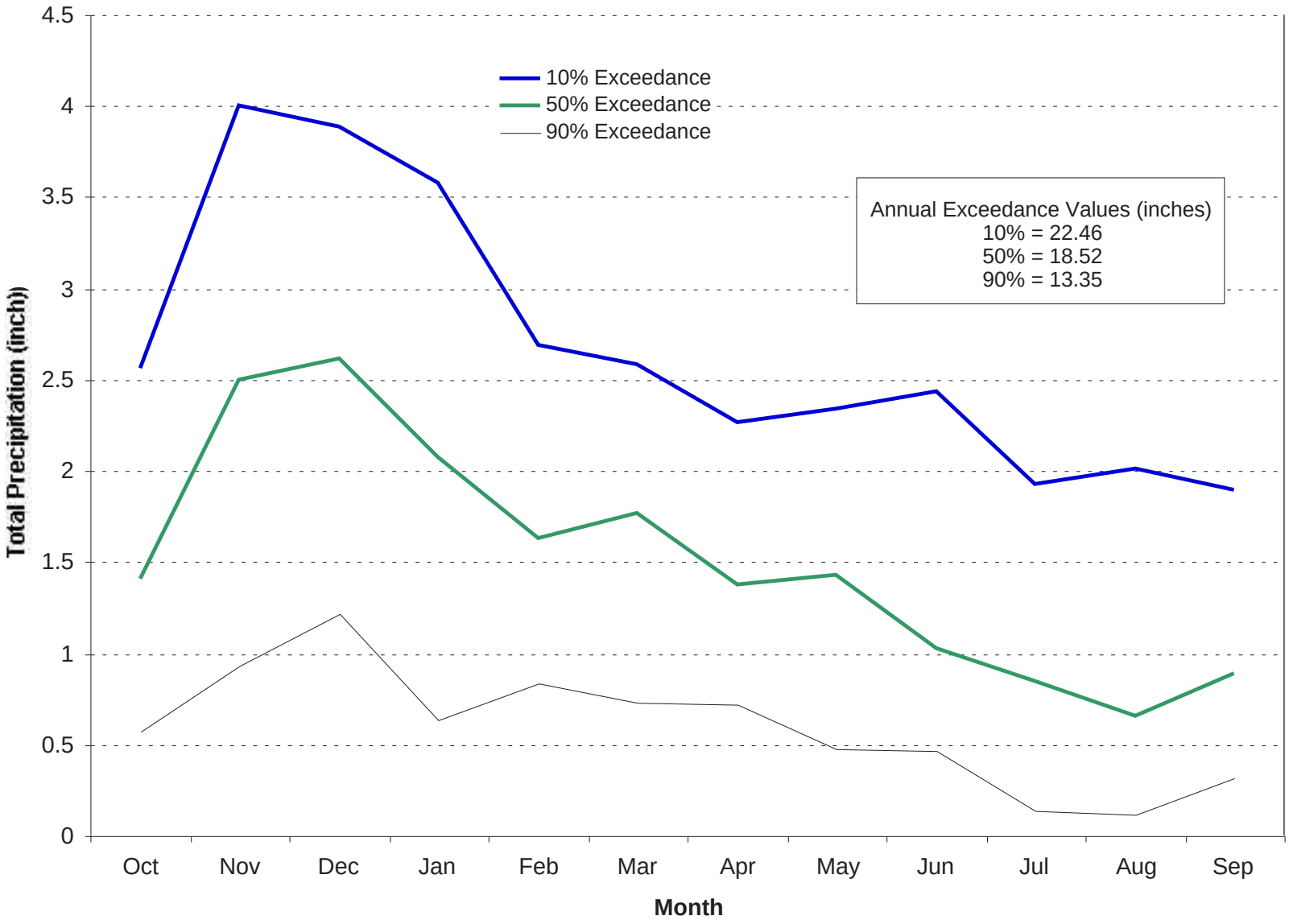
Source: National Resources Conservation Service

Figure 2-4
Monthly Average Precipitation
Mount Crag
Period of Record 1990-1999



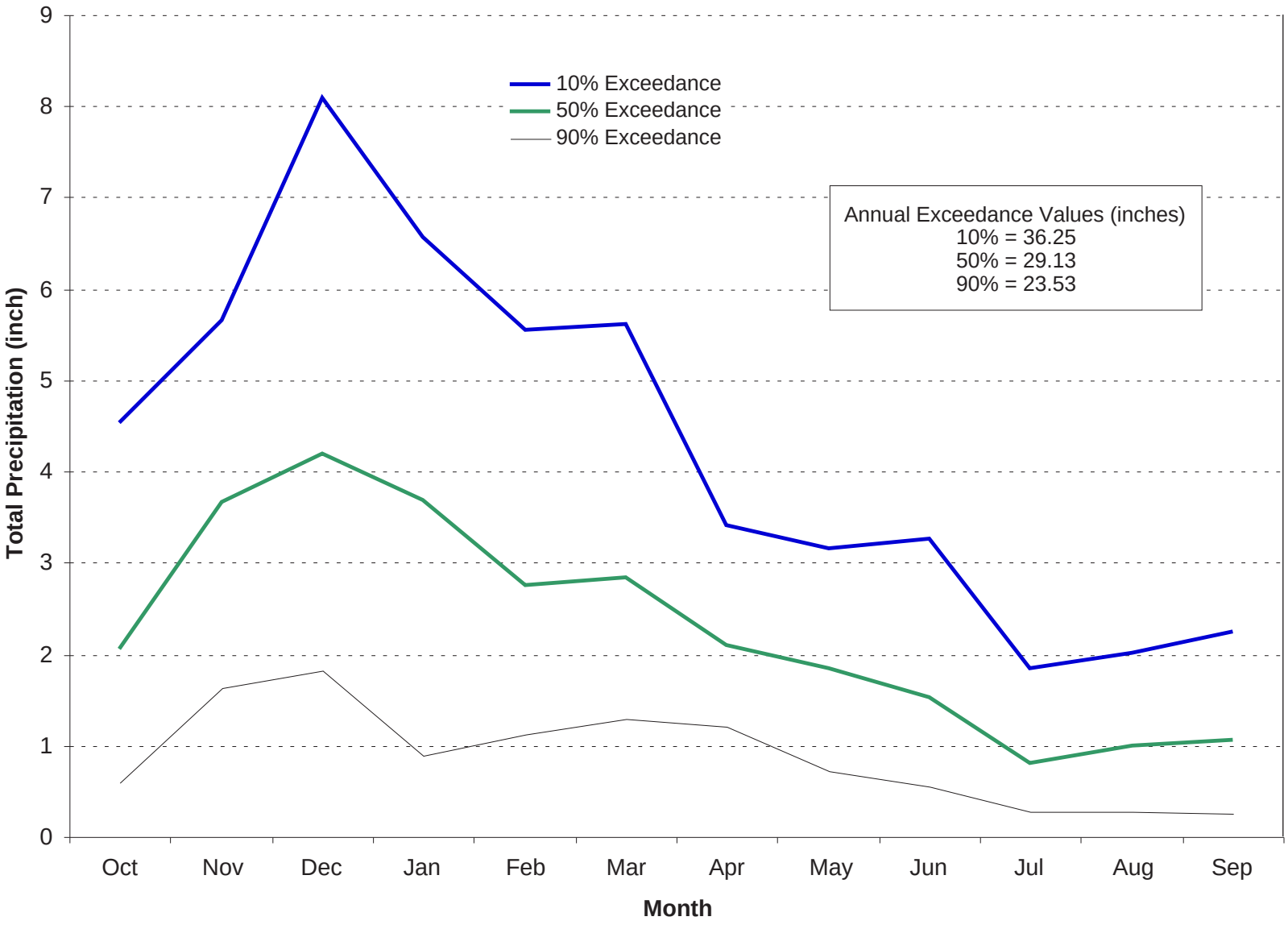
Source: NOAA National Weather Service and
Natural Resouces Conservation Service

Figure 2-5
Precipitation Expressed as Monthly Percentage of Annual Total



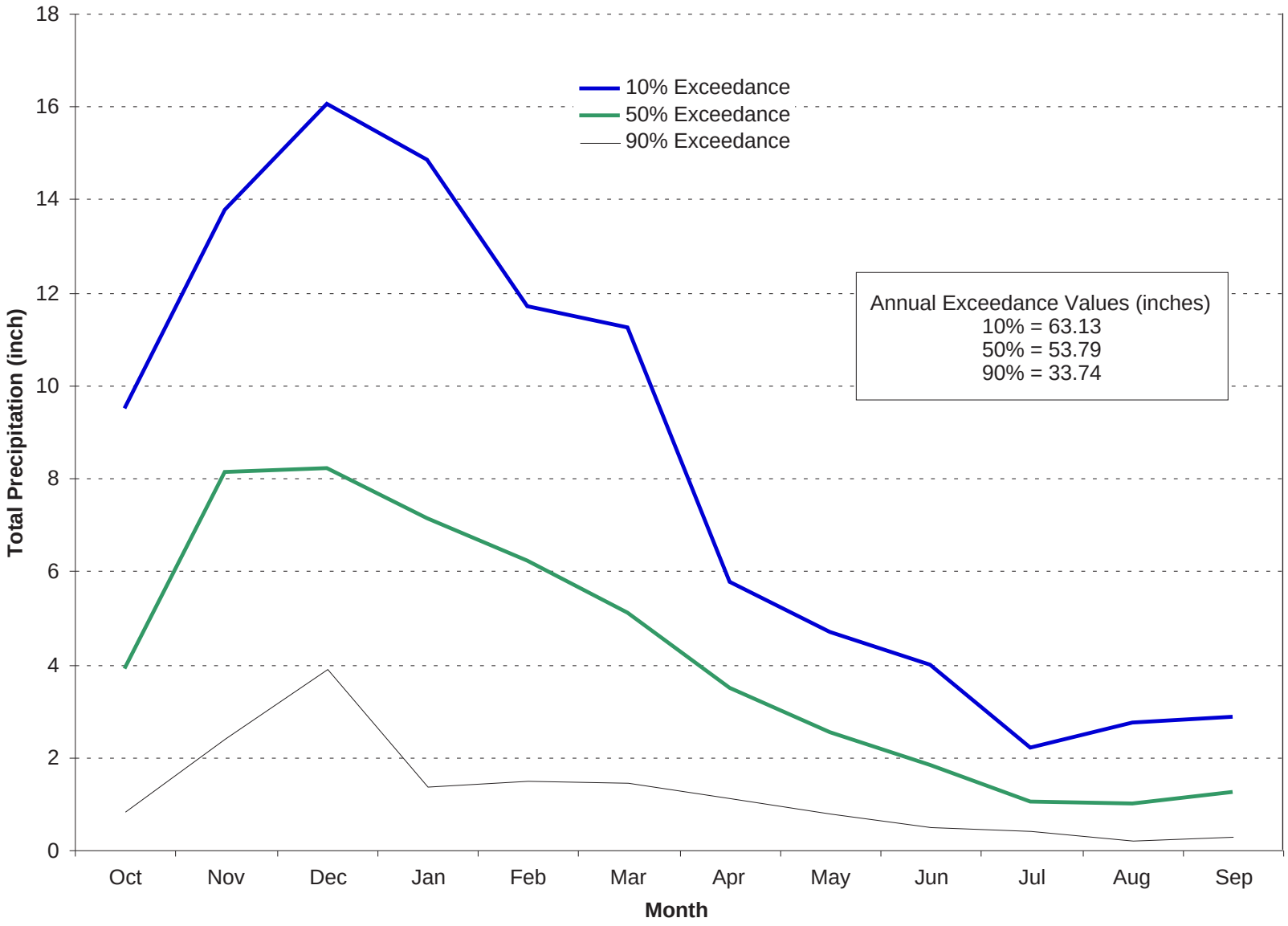
Source: NOAA National Weather Service

Figure 2-6
Exceedance Values
Port Townsend Precipitation
Period of Record 1948-1999



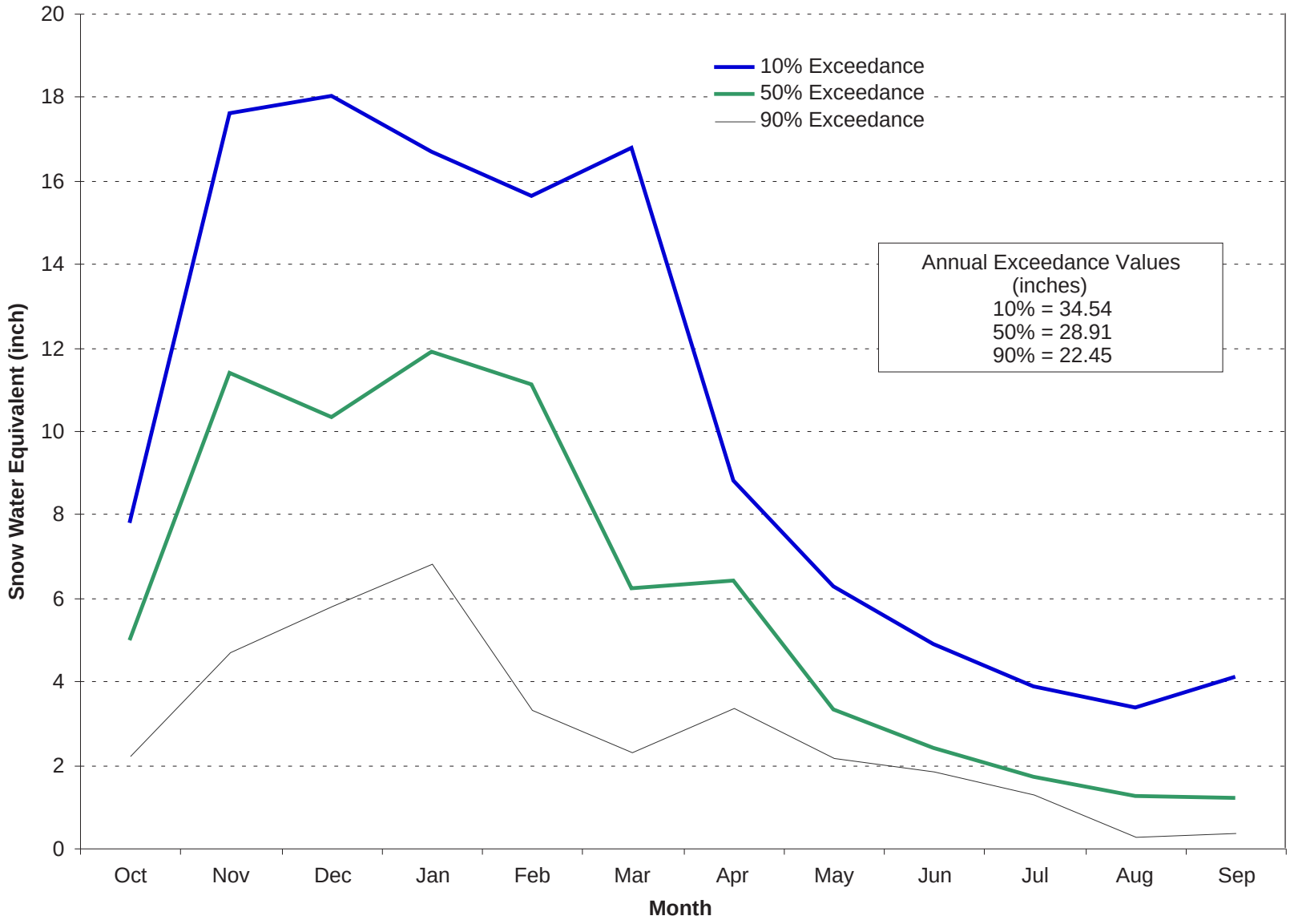
Source: NOAA National Weather Service

Figure 2-7
Exceedance Values
Chimicum Precipitation
Period of Record 1948-1999



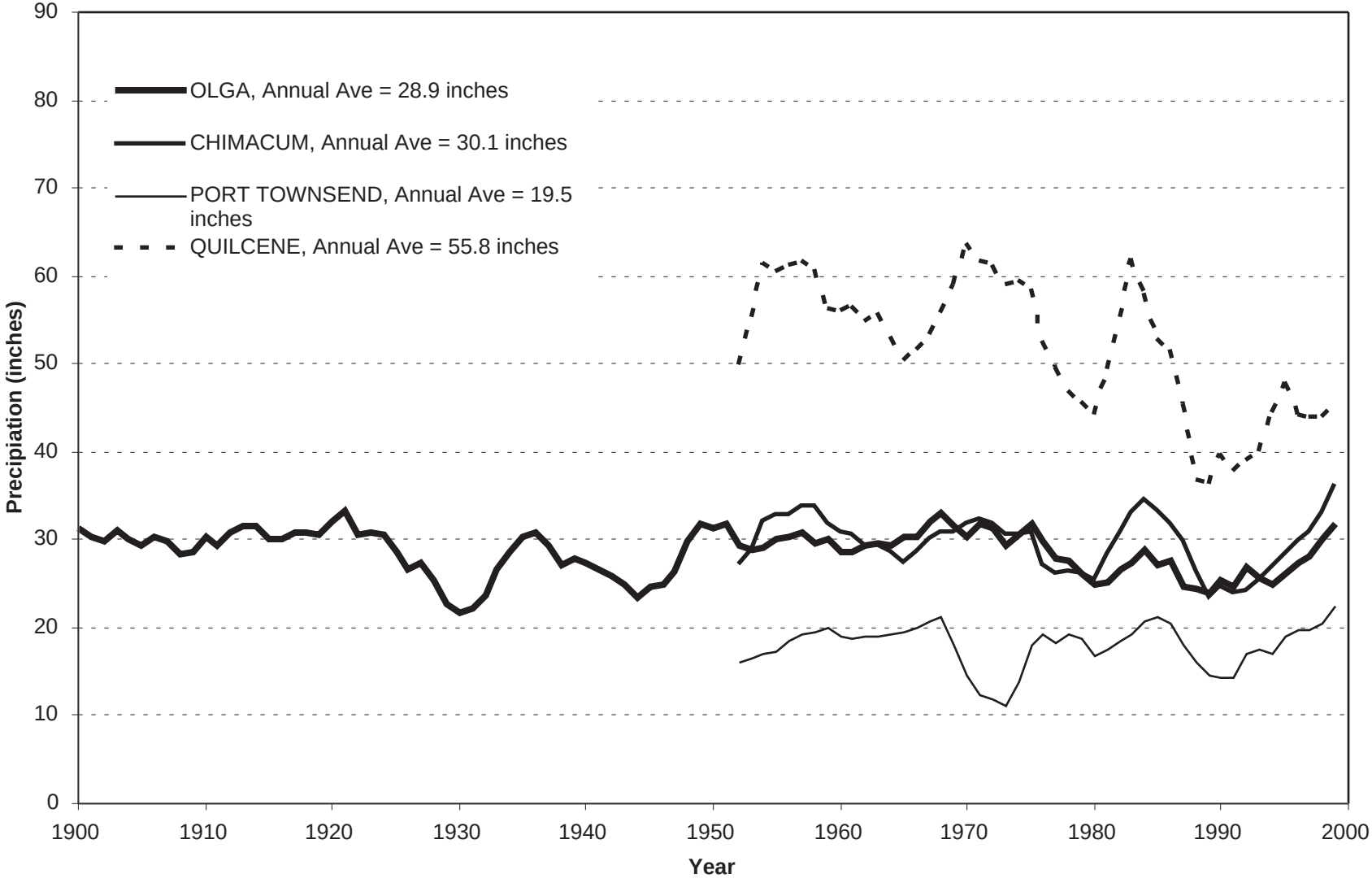
Source: NOAA National Weather Service

Figure 2-8
Exceedance Values
Quilcene 2 SW Gage Precipitation
Period of Record 1948-1999



Source: Natural Resources Conservation Services

Figure 2-9
Exceedance Values
Mount Crag Precipitation
Period of Record 1990-1999



Source: NOAA National Weather Service

Figure 2-10
Trends in Annual Precipitation
5-Year Moving Average

3. WATER QUALITY

This section of the assessment discusses surface water and groundwater quality in WRIA 17. Water quality parameters and monitoring results are generally summarized for the entire WRIA. Readers should refer to specific sub-basin chapters (Sections 8 through 17) for more detailed sub-basin specific discussion of surface water and groundwater quality.

3.1 SURFACE WATER QUALITY

3.1.1 Scope and Objectives

The surface water quality data summary examined available marine and freshwater surface water quality for WRIA 17. The data assessment and summary addresses and evaluates information from previous published watershed studies, water quality reports and data available from existing databases. The data assessment includes identification and analysis of water quality limited stream segments, previous monitoring locations, and point and non-point pollution sources. Identification of data quality and quantity, and potential data gaps are also provided.

3.1.2 Water Body Classifications

Surface waters in the state of Washington are classified into one of four classes: AA, A, B, and C according to the intended use of the water body (WAC 173-201A-030). Each classification has water quality criteria to support the variety of stream or stream segment uses for public health and enjoyment, and for the protection of fish and wildlife.

All marine waters in WRIA 17 (e.g., Hood Canal, Admiralty Inlet, Sequim Bay) are classified as AA waters except for a portion of Port Townsend Bay west of a line between Point Hudson and Kala Point which is classified as Class A. All rivers and streams in WRIA 17 are Class AA because they feed into the Hood Canal, Strait of Juan deFuca, Puget Sound, or are located in the Olympic National Forest (Chapter 173-201A WAC). Water quality in Class AA waters is considered extraordinary, markedly and uniformly exceeding requirements for all or substantially all uses. Water quality for Class A waters is considered excellent, meeting criteria for all uses, but not markedly or uniformly.

3.1.3 State of Washington Water Quality Standards

Water quality standards for surface water differ for each class based on the intended use of the water body. The following parameters have been selected for specific discussion based on their prevalence in existing WRIA 17 data, and their importance to the uses of the WRIA 17 water bodies. Water quality standards for these parameters in Class AA and Class A freshwater streams are listed in Table 3-1. Marine water quality standards for Class AA and A waters are listed in Table 3-2.

3.1.3.1 *Fecal Coliform*

Fecal coliform (FC) bacteria are a sub-group of coliform bacteria. Coliform bacteria are a group of microorganisms found in the feces of all warm-blooded animals, although these bacteria are not unique to feces. In water, coliform organisms are typically used as an indicator of the potential presence of disease-causing organisms. The presence of FC in water indicates the potential microbial degradation of water, and although FC do not effect fish or shellfish themselves, shellfish do retain these microoranisms through the process of filter feeding. Human consumption of shellfish from areas contaminated with FC can create a possible health risk.

Table 3-1. Water Quality Standards for Freshwater (WAC 173-201A)

Parameter	Class AA	Class A
Fecal Coliform	Geo. Mean <50 colonies /100 mL and <10% of samples >100 colonies/100 mL	Geo. Mean <100 colonies /100 mL and <10% of samples >200 colonies/100 mL
Dissolved Oxygen	>9.5 mg/L	>8.0 mg/L
Temperature	<16.0 C or, if >16 C due to natural conditions, no human-caused increases of 0.3 C.	<18.0 C or, if >18 C due to natural conditions, no human-caused increases of 0.3 C.
	Point source activities shall not exceed t=23/(T+5), Non-point source activities shall not exceed 2.8 C	Point source activities shall not exceed t=28/(T+7), Non-point source activities shall not exceed 2.8 C
pH	6.5-8.5 with a human caused variation of <0.2 within the range	6.5-8.5 with human caused variation of <0.5 within the range
Turbidity	<5 NTU over background (50 NTU or less) or <10% increase when background is >50NTU	<5 NTU over background (50 NTU or less) or <10% increase when background is >50NTU
Toxic, radioactive, or deleterious material	Below levels which adversely affect biota or public health	Below levels which adversely affect biota or public health
Aesthetic values	No impairment that offends sight, smell, touch, or taste.	No impairment that offends sight, smell, touch, or taste.

t = maximum permissible temperature increase measured at a mixing zone boundary.

T= background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.

Table 3-2. Water Quality Standards for Marine Water (WAC 173-201A)

Parameter	Class AA	Class A
Fecal Coliform	Geo. Mean <14 colonies /100 mL and <10% of samples >43 colonies /100 mL	Geo. Mean <14 colonies /100 mL and <10% of samples >43 colonies /100 mL
Dissolved Oxygen	>7.0 mg/L or, if <7 mg/L due to natural conditions, then human caused degradation must be < 0.2 mg/L	>6.0 mg/L or, if <6 mg/L due to natural conditions, then human caused degradation must be < 0.2 mg/L
Temperature	<13.0 C or, if >13 C due to natural conditions, no human-caused increases of 0.3 C.	<16.0 C or, if >16 C due to natural conditions, no human-caused increases of 0.3 C.
	Point source activities shall not exceed t=8/(T-4), Non-point source activities shall not exceed 2.8 C	Point source activities shall not exceed t=12/(T-2), Non-point source activities shall not exceed 2.8 C
pH	7.0-8.5 with a human-caused variation of <0.2 within the range	7.0-8.5 with human-caused variation of <0.5 within the range
Turbidity	<5 NTU over background (50 NTU or less) or <10% increase when background is > 50NTU	<5 NTU over background (50 NTU or less) or <10% increase when background is >50NTU
Toxic, radioactive, or deleterious material	Below levels which adversely affect biota or public health	Below levels which adversely affect biota or public health
Aesthetic values	No impairment that offends sight, smell, touch, or taste.	No impairment that offends sight, smell, touch, or taste.

t = maximum permissible temperature increase measured at a mixing zone boundary.

T= background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.

3.1.3.2 *Turbidity*

Turbidity is the cloudy appearance of a liquid produced by light scattered from suspended, colloidal, or dissolved matter and can be an indirect measurement of sedimentation potential. Turbidity is measured in nephlometric turbidity units (NTU). Turbidity levels in drinking water cannot exceed 5 NTU as regulated by state and federal law. The use of unfiltered surface water by the City of Port Townsend requires this higher standard of water quality. Water quality standards for surface water not allocated for unfiltered drinking water are more lenient, which limits impacts to background turbidity levels to 5 NTU or 10 percent, which ever is less. Suspended solids can settle (sedimentation), which is one of the most common causes of the loss of salmon and trout spawning areas. Sedimentation can also depress benthic invertebrates, and therefore the growth of fish that feed on them, and is also detrimental to shellfish. Photosynthesis can be depressed, and if the suspended solids have high organic matter, they can cause oxygen depletion (LWMC 1991).

3.1.3.3 *Temperature*

Temperature influences chemical and biological reactions, directly effecting aquatic biota and therefore the regulation of the ecosystem. Higher temperatures cause biological processes to proceed faster. The higher the temperature, the less oxygen will remain dissolved in the water due to accelerated loss of oxygen to the atmosphere and the increased use of oxygen to break down the organic material made because of increased metabolic rate (LWMC 1991).

Temperature is a primary factor controlling salmonid growth and reproduction. The maximum weekly average temperature for growth for coho salmon and Sockeye salmon is 18 degrees Celsius. The maximum weekly average temperature for spawning coho and Sockeye salmon is 10 degrees Celsius during the spawning months. The maximum temperature for embryo survival during the spawning season is 13 degrees Celsius (EPA 1986).

3.1.3.4 *Dissolved Oxygen*

Dissolved oxygen (DO) levels in healthy streams should be above 6 mg/L in Class A marine waters to above 9.5 mg/L in Class AA fresh waters to ensure protection of aquatic life. The criteria applies to coldwater fish in waters containing one or more species in the family *Salmonidae* or other sensitive coldwater fish. The DO acute lethal limit for salmonids is at or below 3 mg/L (EPA 1986). Dissolved oxygen is consumed by organisms to decompose organic material, and there must be sufficient amounts present to keep aerobic organisms (bacteria, fish, etc.) alive and healthy.

3.1.3.5 *pH*

The pH of a solution is given by the negative logarithm of the hydrogen ion concentration. The hydrogen ion concentration is a measure of the acidity of a solution. Acidic conditions are less than 7, neutral is 7, and alkaline is above 7. Most organisms function best in near neutral solutions. The pH of water affects aquatic organisms directly, and also indirectly by controlling the equilibrium of other life-threatening reactions (e.g., ammonia, hydrogen sulfide, and heavy metals reactions). The pH is a controlling factor in the toxicity of heavy metals such as copper, lead, mercury and cadmium. At higher pH's, metals tend to bind with sediment particles, which render them nontoxic. In dissolved forms at lower pH's, metals become dissolved and can be toxic to fish and other aquatic organisms. Metals such as mercury and cadmium bioaccumulate in fish, and become toxic to humans. Class AA and A freshwater streams should have pH levels between 6.5 and 8.5. Class AA and A Marine water should have pH levels between 7.0 and 8.5 (LWMC 1991).

3.1.3.6 *Total Suspended Solids*

Total suspended solids (TSS) is a measurement of the amount of solids suspended in solution by weight. TSS is not correlated with turbidity, which is a measure of light scatter, but both are measurements of suspended matter, which is a cause of sedimentation, which is discussed in the section on turbidity. There is no numerical water quality criterion for TSS established for the state of Washington surface waters. The national criteria for solids for the benefit of freshwater fish and other aquatic life is as follows: Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life (EPA 1986). Suspended solids affect fish and fish food populations by (1) either killing fish or reducing their growth rate and resistance to disease, (2) preventing successful development of fish eggs and larvae, (3) modifying natural movements and migrations of fish, and (4) reducing the abundance of food available to the fish (EPA 1986).

3.1.3.7 *Total Phosphorus as Phosphate*

Phosphate is one of the major nutrients required for plant nutrition and is essential for life. In excess of a critical concentration, phosphates stimulate plant growth. High phosphorus concentrations are associated with accelerated eutrophication of waters, reservoirs and lakes that collect phosphates from influent streams and store a portion of them within consolidated sediments, thus serving as a phosphate sink. Total phosphorus (TP) in excess of 25 μg/L during the spring turnover may stimulate excessive or nuisance growths of algae and other aquatic plants in lakes or reservoirs. A desired goal for the prevention of plant nuisances in streams not discharging directly to lakes is 100 μg/L of TP (EPA 1986).

3.1.3.8 *Nitrate as Nitrogen*

Growing plants assimilate nitrate or ammonium ions. In oxygenated natural water systems nitrite is rapidly oxidized to nitrate. The nitrite ion is formed from the nitrate or ammonium ions by certain microorganisms found in soil, water, sewage, and the human digestive tract. In quantities normally found in food or feed, nitrates become toxic only under conditions in which they may be reduced to nitrites. The reaction of nitrite with hemoglobin can be hazardous in human infants under 3 months. Therefore, nitrate as nitrogen (NO3-N) should not exceed 10 mg/L in a drinking water supply. Since concentrations of nitrate or nitrite that would exhibit toxic effects on fish could rarely occur in nature (the chronic LC50 value for chinook salmon was determined to be 1,050 mg/L NO3-N in fresh water and 900 mg/L NO3-N in marine water), restrictive criteria have not been recommended in surface waters not designated for a drinking water supply.

3.1.4 Shellfish Harvesting Standards

The National Shellfish Sanitation Program (NSSP) requires a shoreline survey and a growing area standard to classify a shellfish growing area. The shoreline survey locates and evaluates all significant point and non-point pollution sources along the shorelines and in upland drainage areas. The growing area standard is based on the following FC criteria:

- The geometric mean of FC data shall not exceed 14 per 100 mL, and
- The 90th percentile of the FC data shall not exceed 43 per 100 mL

A minimum of 30 samples is required from each sampling station to determine the required statistics. Samples are taken six times a year from “Approved” areas and once a month from “Conditionally

Approved" areas. Both criteria must be met in order to be compliant with the Growing Area Standard (DOH 1999a).

3.1.5 Summary of WRIA 17 Surface Water Quality

In general, surface water quality in WRIA 17 is good; however, areas of water quality degradation have been identified through previous monitoring efforts. Surface water quality monitoring conducted by Jefferson County, the Jefferson County Conservation District (JCCD), the Point No Point Treaty Council (PNPTC), the DOH and others indicates that the majority of freshwater streams and marine water meet state standards for the parameters measured. The majority of marine and freshwater water quality information collected in WRIA 17 has consisted of fecal coliform (FC) bacteria and temperature data. There is a fair amount of data on physical characteristics such as dissolved oxygen (DO), pH, conductivity, total suspended solids (TSS), and turbidity. There is limited information on nutrients such at total phosphorous (TP) and nitrate (NO3-N). Very little information is available on organic or inorganic toxic compounds.

Under Section 303(d) of the Clean Water Act, the Washington Department of Ecology (Ecology) identifies water bodies that do not meet water quality standards. This list is known as the 303(d) list. The candidate 1998 Section 303(d) List for WRIA 17 is shown in Table 3-3 and identifies over 64,000 feet (over 12 miles) of stream with impaired uses.

Table 3-3. Candidate 1998 Section 303(d) List for WRIA 17

			On 303(d) List ?		
Water Body	**Parameter**	**Location**	**1998**	**1996**	**1994**
Big Quilcene River	Fish Habitat	RM 2.8	Yes	Yes	No
Big Quilcene River	Instream Flow	RM 2.8	Yes	Yes	No
Chicken Coop Creek	Fecal Coliform	Mouth	Yes	Yes	Yes
Chimacum Creek	Temperature	RM 1.0, 3.5, 8.8	Yes	Yes	No
Chimacum Creek	Fecal Coliform	Station 17B100	Yes	Yes	Yes
Dabob and Quilcene Bay	Fecal Coliform	Station 19	Yes	Yes	Yes
Donovan Creek	Temperature	RM 0.2	Yes	No	No
Jackson Creek	Fish Habitat	Mouth	Yes	Yes	No
Johnson Creek	Fecal Coliform	Mouth	Yes	Yes	Yes
Leland Creek	Temperature	RM 0.2	Yes	No	No
Little Quilcene River	Temperature	RM 2.0	Yes	No	No
Marple Creek	Fish Habitat	Mouth	Yes	Yes	No
Ripley Creek	Temperature	RM 0.2	Yes	No	No
Sequim Bay	Dissolved Oxygen	Ecol Station JDF005	Yes	Yes	Yes
Sequim Bay	pH	Ecol Station JDF005	Yes	Yes	Yes
Sequim Bay	PAHs (sediment)	Lat. 48.075, Long. 123.045	Yes	Yes	Yes
Tarboo Creek	Temperature	RM 2.5, RM 0.5	Yes	Yes	No
Thorndyke Creek	Temperature	RM 1.1	Yes	No	No

Source: Candidate 1998 Section 303(d) List Decision Matrix and Ecology (1995).

The Clean Water Act requires Ecology to develop total maximum daily loads (TMDLs) for 303(d) listed waters. A TMDL is a water cleanup plan that includes an analysis of how much pollution a water body can receive and still remain within the standards for the intended uses. The maximum load is the sum of all point and non-point source discharges as well as natural background loading that will not exceed the

loading capacity of the water body. To date, no TMDLs have been established or planned for any impaired WRIA 17 water bodies; however, Ecology has identified that TMDL studies are required in WRIA 17 based on the 1998 303(d) list. Specific areas include:

- Fecal coliform (FC) in Chicken Coop Creek, Chimacum Creek, Dabob Bay and Jackson Creek,
- High temperature in Chimacum Creek, Donovan Creek, Leland Creek, Little Quilcene River, Ripley Creek, Tarboo Creek and Thorndyke Creek,
- Low in-stream flow in the Big Quilcene River, and
- Dissolved oxygen and pH in Sequim Bay.

3.1.6 POTENTIAL SURFACE WATER POLLUTANT SOURCES

Potential surface water pollutant sources in WRIA 17 include both point and non-point sources. According to the Ecology database, total of 114 point sources are located in the WRIA that are currently regulated by individual National Pollutant Discharge Elimination System (NPDES) permits. These point sources include wastewater and stormwater discharges to marine and freshwater receiving waters, as well as discharges to municipal wastewater systems. The Ecology database does not distinguish permit type, so evaluation of the number and type of either stormwater or wastewater permits was not possible as part of this study. Data to evaluate potential trends and specific impacts of these individual point sources were not available for this analysis.

Non-point sources in the WRIA are less well characterized, and generally include a combination of agriculture, on-site septic (OSS), forestry, and urban stormwater run-off. The location of these non-point sources is approximated on each sub-basin map based on existing data and maps from previous reports. Specific non-point sources, to the extent previously identified, have been evaluated for each sub-basin and are presented in the specific sub-basin assessments sections of this report.

Correction of non-point pollution sources has been aggressively pursued in several sub-basins. Jefferson County and the JCCD have corrected more than 30 OSS in the Quilcene Bay watershed. In the Little Quilcene sub-basin an easement established near the mouth of Donovan Creek removed livestock from 25 acres of tidally influenced land and the JCCD oversaw 14,000 feet of fencing to restrict livestock access to streams. Additionally, the JCCD oversaw 20,000 feet of livestock exclusion fencing in the Dabob-Thorndyke sub-basin, 11,000 feet in the Salmon-Snow sub-basin, and 53,000 feet in the Chimacum sub-basin.

3.1.7 Surface Water Quality Data Quality And Quantity

In general, the quality and quantity of surface water quality data are limited in both spatial coverage and temporal extent. The majority of water quality data are greater than five years old, with a significant amount of data approximately 10 years of age. Existing water quality data are also typically limited in spatial extent, parameters sampled, and frequency of sample collection. The majority of previous water quality data has been collected as part of discreet time-limited studies. The most extensive ambient water quality data set in WRIA 17 has been developed by the JCCD. The water quality database developed and maintained by the JCCD was evaluated as part of the data summary, with results presented in individual sub-basin sections.

Non-point source data for WRIA 17 are typically qualitative and lacks specific location information. The location of point and non-point sources and changes over time is difficult to determine over much of the

WRIA due to a general lack of detail and maps of source locations in previous reports and studies. Non-point source mapping in this report generally relies on the limited source mapping information contained in previous studies. Potential forestry related sources, such as erosion or temperature, are generally discussed in several WRIA 17 reports, but not specifically identified or located. For these reasons, the specific location and magnitude of non-point sources are generally not well characterized throughout the WRIA.

Raw temperature data are available for many eastern Jefferson County streams (Bahls 1995-97). These data are located in part in various reports and raw data files at the Port Gamble S'Klallam Tribe (Bahls 2000 personal communication). These data include approximately 15 Hood Canal streams weekly maximum temperature sampling stations monitored for three years, and temperature monitoring at 22 sites along Chimacum Creek in 1995 and four sites in 1996 and 1997. These data are the most comprehensive temperature data for WRIA 17. The data are generally reflected on Ecology's 303(d) list, but to date have not been evaluated in detail. Temperature data for the Big Quilcene River and Penny Creek are available from USFWS from the 1970s to present.

Water quality station locations identified on figures (e.g., Exhibit 3) correspond to specific studies referenced in this report. These station numbers are being updated by JCCD for the database. Therefore, some station locations may be misleading when compared to the updated station identification numbers.

3.2 GROUNDWATER QUALITY

The quality of groundwater in WRIA 17 was evaluated by reviewing existing studies and compiling readily available water-quality data. The most common parameters of concern in WRIA 17 are chloride, nitrate, iron and manganese. Chloride is commonly used as an indicator of saltwater intrusion, and most studies addressing chloride concentrations focus on coastal areas. Elevated concentrations of nitrate typically indicate contamination from septic leachate, animal wastes or fertilizer applications. Iron and manganese occur from natural sources, and can compromise aesthetic qualities of water at higher concentrations. This chapter summarizes the incidence of these four water quality parameters. Previously summarized information is presented from existing studies, and raw chloride and nitrate data have been compiled and plotted on maps. Discussions of sites where groundwater is contaminated with hazardous wastes, data gaps, and recommendations for further study are also included.

Overall, available data indicate that water quality is generally good for the chemical constituents reviewed. Elevated chloride can be problematic in coastal areas, and is sometimes noted in inland areas. Nitrate concentrations are generally far below State drinking water standards and do not pose a health threat. While elevated iron and manganese are common complaints, these constituents are not considered to be health related. Groundwater has been contaminated by human activities at selected locations, but available data do not suggest that existing drinking water supplies have been impaired.

Existing studies addressing groundwater quality in WRIA 17 have been prepared by Ecology, the United States Geological Survey (USGS), and various consultants. Whereas the agency studies typically cover larger portions of the WRIA, consultants' reports often describe more localized areas. Available documents reviewed as part of this assessment either focus explicitly on saltwater intrusion, provide a general overview of groundwater quality as part of a hydrogeologic characterization, or summarize data from public water system sampling performed to meet regulatory requirements.

The occurrence of chloride along coastal regions of WRIA 17 was documented in the early 1970's and early 1980's by Ecology (Walters 1971; Grimstad and Carson 1981), in the mid-1980's by the USGS (Dion and Sumioka 1984), and in the early 1990's by CH2MHill (Forbes and CH2MHill 1993). In

addition, a recent Ecology study provided a detailed look at saltwater intrusion on Marrowstone Island (Sinclair and Garrigues 1994).

Hydrogeologic characterizations which include discussion of groundwater quality were published for Clallam County by the USGS in the mid-1980's (Drost 1986) and the late 1990's (Thomas et al. 1999). In particular, the Thomas report provided a detailed analysis of sources of nitrogen to groundwater. For Jefferson County, only one hydrogeologic characterization addresses groundwater quality (EES and Pacific Groundwater Group 1994).

Consultants' reports which present localized groundwater quality data have been prepared for the Port Ludlow vicinity (Robinson and Noble 1994-1997; Montgomery Water Group 1995), for various satellite water systems owned and operated by the PUD #1 of Jefferson County (Parametrix 1997), and for a test well in the vicinity of Quilcene (Pacific Groundwater Group 1997). While other consultant's reports may exist which provide additional information regarding groundwater quality, no other relevant reports were encountered during this Phase I investigation. In addition, the City of Port Townsend provided a summary of water-quality data from the Tri-Area "Sparling" and "Kivley" wells collected between 1996 to 1999.

Various water-resource databases were used to compile and map chloride and nitrate concentrations measured in wells. A "compiled database" was assembled from databases maintained by the USGS, Ecology, Jefferson County Environmental Health Department (JCEHD), Clallam County Department of Community Development, and other miscellaneous sources. The above-mentioned agencies were contacted and up-to-date versions of their database were provided. The Ecology, USGS, and Clallam County databases are composed largely of water-quality data summarized in existing studies, whereas the Jefferson County and miscellaneous data have not been presented in large-scale characterizations. Miscellaneous data were compiled from the consultants' reports discussed above.

Table 3-4 summarizes the databases compiled in this analysis. Chloride values were compiled for 476 wells, and nitrate values were compiled for 364 wells. Where data were available from multiple sampling events, concentrations were averaged. Time-series analysis was not performed, however temporal trends in chloride were evaluated by Forbes and CH2MHill (1993) and temporal trends in nitrate were evaluated by Thomas et al. (1999).

Table 3-4. Data Used for Groundwater Quality Analysis

Data Source	Sampling Program	Number of Wells with Chloride Data	Number of Wells with Nitrate Data
USGS	various water-resource investigations	119	4
Department of Ecology	new wells (building permit requirements)	93	9
Clallam County Department of Community Development	various water quality studies	n/a	8
Jefferson County Health Department	data submitted from new wells for building permit approval	236	330
Miscellaneous Consultant's Reports	generally required for regulatory compliance	28	13

Incidents of groundwater contamination with hazardous substances and/or from leaking underground storage tanks (LUSTs) are regularly summarized by Ecology and made available to the public. Updated lists of LUSTs (March 22, 2000), hazardous sites (February 29, 2000), confirmed and suspected

contaminated sites (November 29, 1999), and groundwater contamination that affects drinking water (April, 1999) were compiled and summarized in this study.

Several sources of data were not considered in this study. DOH maintains files containing water quality reports from public water systems. All water systems are required to sample for a suite of inorganic parameters at least once, while further sampling and additional parameters are required for larger systems. Two digital databases are maintained, one that lists all water quality results submitted, and one that lists exceedances of drinking water MCLs only. Data from these sources were not provided over the course of this study. In addition, residents of Marrowstone Island have been measuring chloride concentrations in groundwater, surface water, and rainfall. The water samples are analyzed with a field kit, and are not submitted to a certified laboratory.

3.2.1 Chloride

Elevated chloride concentrations in groundwater can indicate saltwater intrusion, other sources of contamination, or special cases of natural chloride occurrence. In coastal areas, aquifers with direct hydraulic continuity to the sea typically contain both fresh water and saltwater, with the lower density freshwater "floating" above the higher density saltwater. A mixing zone, called the "zone of diffusion", provides a transition from freshwater concentrations (typically less than 30 mg/l) to saltwater concentrations (on the order of 19,000 mg/l). The freshwater zone is typically thinnest near the coast, and becomes thicker in an inland direction. The saltwater forms a "wedge" beneath the freshwater, that deepens with distance inland. The position of the saltwater wedge is determined by the amount of freshwater recharge available to displace the underlying saltwater and by aquifer hydraulic properties. A dynamic equilibrium is formed between the freshwater and saltwater that can be disturbed by groundwater pumping. Pumping can cause the saltwater wedge to move inland (lateral intrusion), or locally upward towards the well intake (upconing).

Not all wells with high chloride concentrations are affected by saltwater intrusion. In some cases, wells may show high chloride concentrations because they are completed within the natural zone of diffusion. While pumping such a well may increase (naturally high) chloride concentrations, the problem at hand is more due to the choice of well location than of pumping-induced saltwater intrusion. Naturally elevated chloride concentrations may also occur in aquifers with no direct hydraulic connection to the sea or in areas far enough inland that the saltwater wedge does not underlie the well. Even aquifers with bottom elevations above sea level (therefore above the maximum elevation of the saltwater wedge) have shown elevated concentrations due to chloride trapped within pore spaces or fractures from prior events in the geologic history of the aquifer material. This can occur when marine sediments include saltwater from the time of deposition ("connate" saltwater), when saltwater extended further into aquifers due to higher relative sea level during portions of the ice age ("relict" saltwater); and if pre-historic tidal waves (tsunamis) have added chloride to above-sea-level aquifers. Due to permeability variations in the aquifers and variations in hydraulic gradient groundwater flow system, some areas may not receive the same amount of groundwater "flushing" as others.

Chloride concentrations can increase as a result of anthropogenic contamination. Landfill leachate may show high chloride concentrations, and septic effluent may also show above "background" chloride levels. In the case of landfills, however, contamination would likely be localized to areas near the site. Chloride releases due to septic discharge are typically not sufficiently large to cause the concentrations of concern discussed in this analysis, except possibly in very localized situations.

The chloride concentrations contained in the compiled database were divided into five categories, as shown in Table 3-5 below. In coastal areas where hydraulic continuity exists between groundwater and

marine water, these categories (in order of increasing concentration) represent increasing potential for (or severity of) saltwater intrusion.

Table 3-5. Chloride Data Summary

Concentration Range	Interpretation	Occurrence
<50 mg/l	natural (background) concentration	70 % of samples
≥50 mg/l, <100 mg/l	May warrant "concern" regarding saltwater intrusion	11 % of samples
≥100 mg/l, <250 mg/l	indicates onset of saltwater intrusion	9 % of samples
≥250 mg/l, <1000 mg/l	indicates advanced saltwater intrusion	8 % of samples
≥1000 mg/l	indicates severe saltwater intrusion	2 % of samples

The compiled database contains 476 wells with chloride data. Measured chloride concentrations were averaged for wells with multiple sampling events. Most of the wells are located within a mile of the coast, although inland wells are included in the analysis (Exhibit 4). While the majority of wells exhibit chloride concentrations in the "background" range, 30 percent of the wells show some sign of elevated chloride concentrations. The summary table above shows that wells with elevated chloride concentrations are near evenly distributed between the 50 to 100 mg/l range, the 100 to 250 mg/l range, and the 250 to 1000 mg/l range. Few wells exhibit concentrations in excess of 1000 mg/l, a value indicating severe intrusion or very poor well siting.

The relationship between chloride concentration and well depth was evaluated by comparing the degree to which wells completed in different depth ranges populate the four concentration ranges discussed above. Figure 3-1 presents a graph of the chloride concentration distributions for wells up to 100 feet deep, wells between 100 and 200 feet deep, and wells deeper than 200 feet. Little difference was noted between the three populations, although the deeper wells (>200 feet) had a slightly higher percentage of background-range chloride concentrations. The reasons for this apparent anomaly are unclear. Had this analysis been performed for well completion elevation as opposed to well depth, wells completed above sea level might have shown lower chloride concentrations than wells completed below sea level. This is because the saltwater wedge cannot rise to elevations above sea level. Completion elevation could not be calculated for wells from the JCEHD database at the time of this writing. Even if completion elevation data were available, a multitude of factors influence the likelihood of saltwater intrusion, and their combined effects are likely to overshadow the influence of elevation alone. Other factors include distance from the coastline, groundwater elevation (hydraulic head), and the density and intensity of local groundwater withdrawals.

The geographic distribution of elevated chloride concentrations is discussed for each sub-basin in Chapters 7-18 and is shown in Exhibit 4. Isolated instances of coastal wells with elevated chloride concentrations are found in all sub-basins with significant coastal exposure. They are noted along Discovery Bay and the Miller Peninsula coastline, at Kala Point, Oak Bay, Port Ludlow, Coyle, Jackson Cove, and other locations. While isolated instances of high chloride in coastal wells reveal the potential for specific, localized problems, they say little about the severity of saltwater intrusion potential in that sub-basin. Some sub-basins, however, show a notably high incidence of wells with elevated chloride concentrations. Elevated chloride is common over much of Marrowstone Island, along portions of the Ludlow sub-basin coastline, in inland locations in the Big and Little Quilcene sub-basins, along west Sequim Bay, and near Gardiner in the Miller sub-basin.

It should be emphasized that elevated chloride encountered in individual wells in particular locations does not mean that all wells drilled at these locations will encounter high chlorides. The factors controlling

occurrence of elevated chloride in coastal areas are multiple and complex. Where more than one aquifer is present, chloride concentrations can vary significantly between aquifers.

Large, localized groundwater withdrawals have greater potential to cause saltwater intrusion than small, geographically distributed groundwater withdrawals. In general, caution is warranted when developing groundwater in coastal areas where elevated chloride concentrations are commonplace. In contrast to coastal areas, pumping from inland areas with naturally high chloride concentrations is less likely to cause increased concentrations over time. High chloride in inland areas may be due to poor quality water "trapped" in aquifer materials and/or a slow rate of "flushing" through the affected portion of the aquifer.

3.2.2 Nitrate

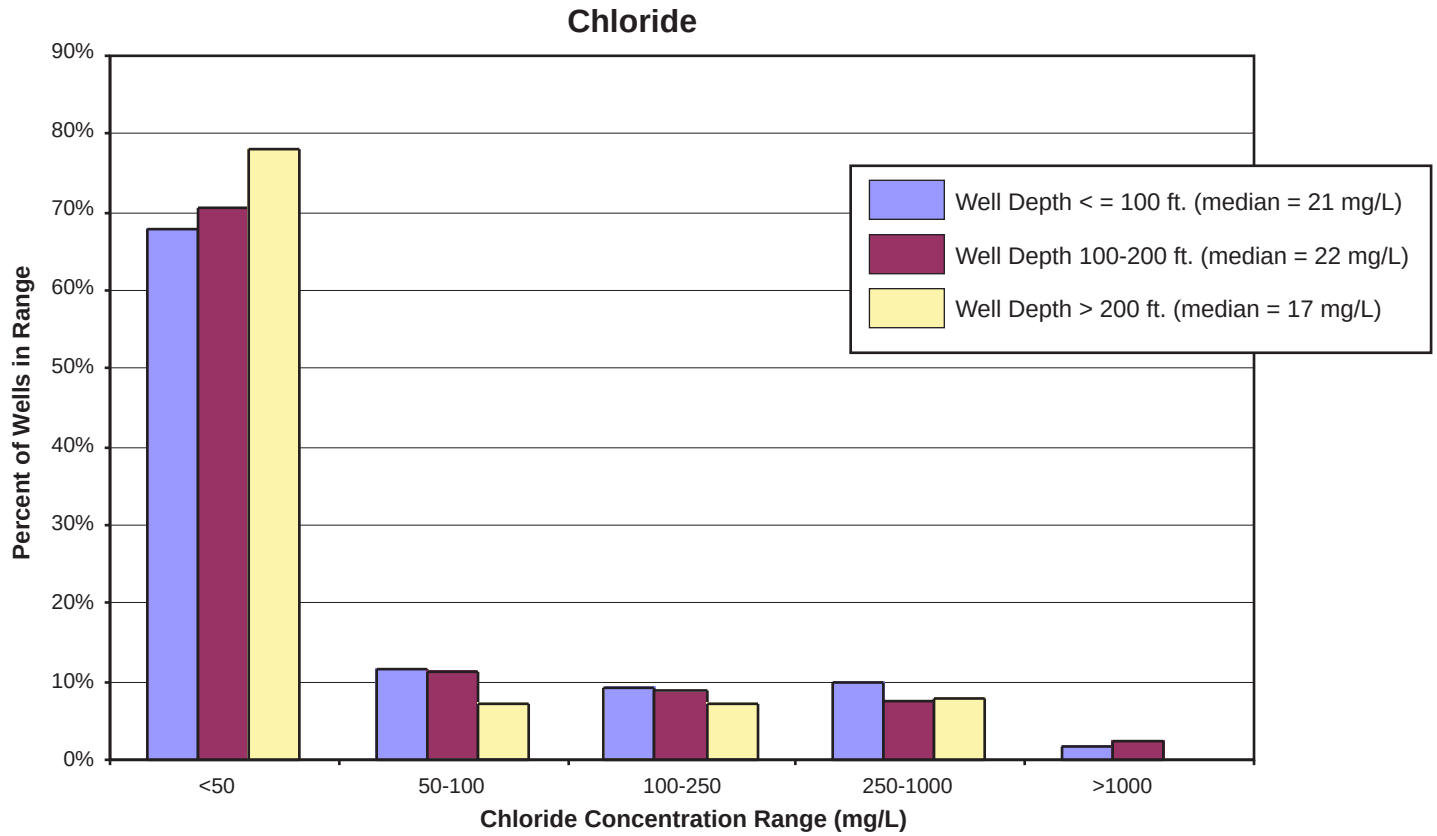
The geographic distribution of nitrate can reflect the occurrence of groundwater contamination from sewage, animal waste, industrial waste or nitrogen rich fertilizers. The State primary drinking water MCL for nitrate (as N) is 10 mg/l. Concentrations above this limit can inhibit the oxygen-carrying capacity of blood and may cause methemoglobenemia (blue baby syndrome) in infants. Precipitation typically contains between 0.3 and 2.5 mg/l of nitrate, although coastal areas commonly show values between 0.15 and 0.5 mg/l (Matthess 1982). Concentrations in groundwater which exceed typical rainfall values are often considered to be impacted by human (or animal waste) sources of contamination, although mildly elevated concentrations may occur due to breakdown of organic matter in organic-rich soils. For the purpose of this analysis, natural "background" concentrations of nitrate (e.g. unaffected by human activity) were assumed to be typically 1.0 mg/l or less. This cutoff limit is based on a study of the Sequim-Dungeness area that showed 95 percent of groundwater samples taken beneath natural grasslands or forests to have nitrate concentrations below 1.0 mg/l (Thomas et al. 1999). Slightly higher background concentrations may occur in areas of organic-rich soils.

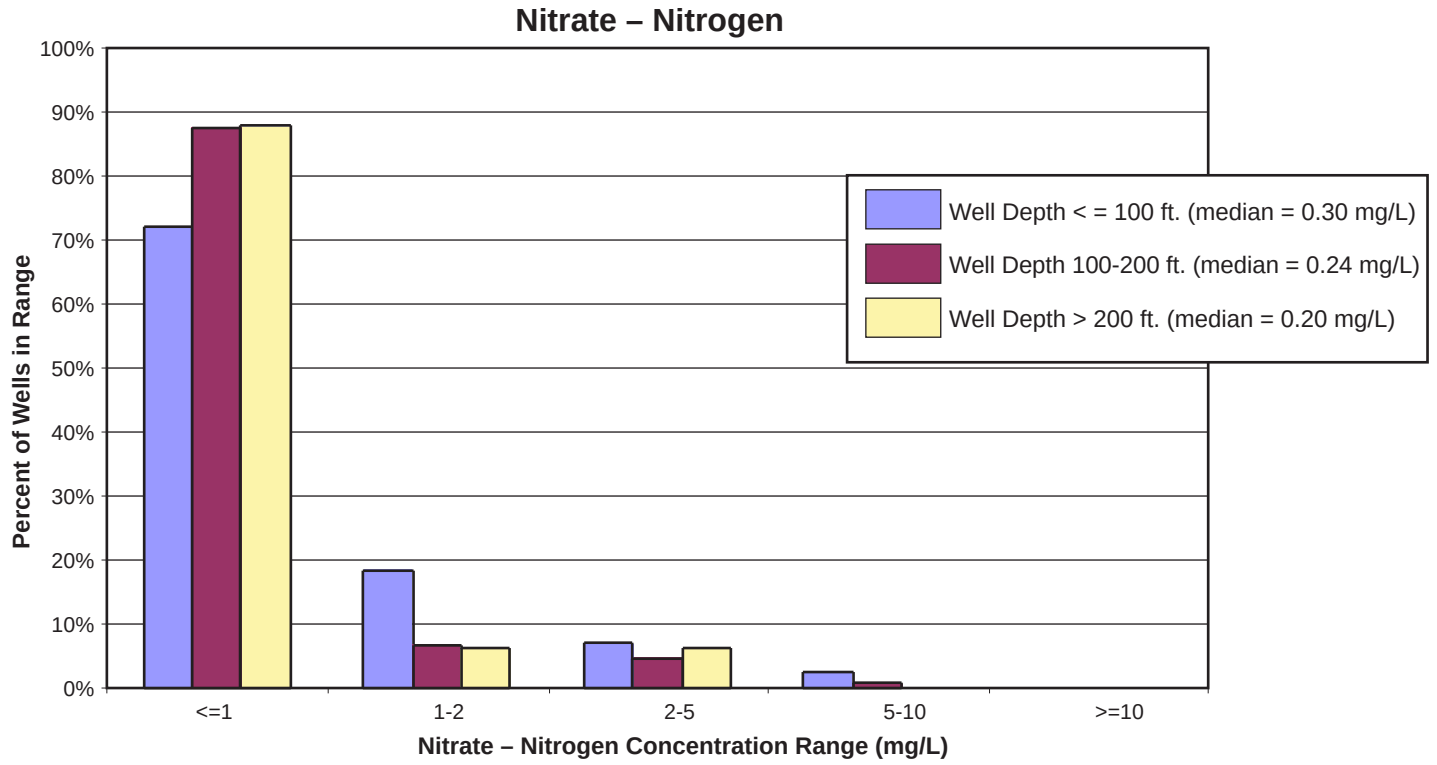
The nitrate concentrations contained in the compiled database were divided into five categories, as shown in Table 3-6 below. Throughout this report, all nitrate values are expressed is nitrogen ("nitrate as N"). In order of increasing concentration values, these categories represent increasing likelihood of contamination from anthropogenic sources of nitrogen.

Table 3-6. Nitrate Data Summary

Concentration Range (NO_3 as N)	Interpretation	Occurrence
≥1 mg/l	natural (background) concentration	82 % of wells
>1 mg/l, ≤2 mg/l	mildly elevated, possibly due to anthropogenic sources	10 % of wells
>2 mg/l, ≤5 mg/l	elevated, probably due to anthropogenic sources	6 % of wells
>5 mg/l, <10 mg/l	highly elevated due to anthropogenic sources	1 % of wells
≥10 mg/l	contaminated above MCL due to anthropogenic sources	no wells

The compiled database contains 364 wells with nitrate data. Measured nitrate concentrations were averaged for wells with multiple sampling events. The majority of sampled wells (82 percent) showed nitrate concentrations within the natural (background) range, and 10 percent of wells showYed slightly elevated nitrate concentrations. Both of these categories are far below State Drinking Water MCL and present little cause for concern. The remaining 7 percent showed either elevated concentrations or highly elevated concentrations, however no wells exceeded the state drinking water MCL. Overall, groundwater in WRIA 17 groundwater is not greatly impaired by nitrate contamination.





Source: JCCD

Figure 3-1
Comparison of Chloride and Nitrate Concentration as a Function of Well Depth

Nitrate concentrations were compared to well depth to evaluate differences in water quality between shallow and deep groundwater. Wells up to 100 feet deep were differentiated from wells between 100 and 200 feet deep and from wells deeper than 200 feet. This division supported a rough analysis of the presence of elevated nitrate concentrations as a function of depth in the groundwater flow system. Figure 3-1 presents a comparison of the nitrate-concentration and well-depth ranges listed above. A slight trend can be differentiated, where shallower wells tend to have higher nitrate concentrations than deeper wells. Median nitrate concentrations for each group of wells also show a decrease with greater depth. This relationship is expected because shallow aquifers are closer to nitrogen sources and more time is required for nitrate to migrate from the land surface to deeper aquifers. The same relationship was observed in the Sequim-Dungeness area by Thomas et al. (1999).

The geographic distribution of elevated nitrate concentrations is discussed for each sub-basin in Chapters 7-18 and is shown in Exhibit 5. Instances of mildly elevated nitrate occur in most sub-basins, with most notable nitrate occurrence apparent in the Indian-Marrowstone, Chimacum, Dabob-Thorndyke, and Little Quilcene sub-basins and slightly lesser occurrence observed in the Quimper and Ludlow sub-basins. Reported nitrate concentrations were especially low for the Miller and West Sequim Bay sub-basins, although little data were available for these areas. The remaining eight sub-basins exhibit at least several instances of elevated nitrate (2 to 5 mg/l). In most cases, available nitrate data are too sparsely distributed to determine the lateral extent of elevated nitrate concentrations. Extensive areas of elevated nitrate are generally not observed in areas where the available data are relatively densely distributed. In lower density rural residential areas, it is fairly common for elevated nitrate to occur in a “spotty” distribution due to the localized nature of potential causes such as failing septic systems, poorly sited septic systems, poorly constructed wells, or poorly sited wells. Conditions that support more extensive distributions of elevated nitrate include higher density, unsewered residential areas and extensive agricultural areas with fertilizer use or multiple feedlots.

Several areas are noted where wells with elevated nitrate concentrations appear to be geographically clustered together. In the upper reaches of the Chimacum watershed, an apparent cluster of elevated nitrate wells is situated within a larger number of wells showing background concentrations. In this case, multiple instances of localized nitrate contamination appear to be suggested. On Marrowstone Island, a small cluster of wells with mildly elevated and elevated nitrate concentrations is observed east of Mystery Bay. In other areas where neighboring wells share elevated nitrate concentrations the distances between data points are too large to infer extensive occurrence of nitrate contamination.

3.2.3 Iron and Manganese

Iron and manganese are commonly occurring constituents of groundwater in western Washington. They are derived naturally from the weathering of minerals within the groundwater flow system. Although manganese is much less abundant than iron in rocks and minerals, the two are similar in chemical behavior and are frequently found in association. The solubility of iron and manganese is strongly influenced by the pH and oxidation state of groundwater. Dissolved iron and manganese are typically limited to trace concentrations in oxygenated groundwater, but occur at significant concentrations under reducing conditions. Anthropogenic groundwater contamination which alters the pH and oxidation state of groundwater (e.g. landfill leachate) can cause particularly high concentrations of iron and manganese. Iron and manganese are regulated as secondary (aesthetic) contaminants to drinking water, with MCLs of 0.3 mg/l and 0.05 mg/l, respectively. Concentrations above these MCLs are generally not considered health problems, but impair the taste and can encrust plumbing and stain laundry.

Exceedance of iron and manganese MCLs is a common phenomena in WRIA 17. In studying the water resources of Clallam County, Drost (1986) reports that 24 percent of the wells sampled exceeded the iron

MCL and 23 percent exceeded the manganese MCL. Thomas et al. (1999) sampled 74 wells in Clallam County, and found that 8 percent exceeded the iron MCL with no apparent correlation to well depth. While only a small fraction of the wells sampled in either study are likely to reside in WRIA 17, the reported results demonstrate how common elevated concentrations of iron and manganese can be in geologic deposits similar to those in WRIA 17.

In Jefferson County, high iron and manganese concentrations are also a common occurrence. The JCEHD frequently receives inquiries regarding treatment options for iron and manganese (Christensen 2000 personal communication). A review of water quality data in the JCEHD database indicated that 29 percent of wells had iron concentrations above the MCL (data available from 74 wells) and 29 percent of wells had manganese concentrations above the MCL (data available from 77 wells. PGG and EES (1994) performed a survey of WDOH water system data for the period August, 1988 to August, 1993. The survey indicated 21 incidents of iron and/or manganese concentrations exceeding MCLs among 153 public water systems operating in eastern Jefferson County during this period. This accounts for 14 percent of the reported groundwater sources, and was not differentiated by geographic region or aquifer depth.

No other studies summarize iron and manganese occurrence in Jefferson County, however various consultant's reports indicate that high concentrations occur the PUD Bywater Bay and Shine systems (Parametrix 1997), and the Port Ludlow water system (Montgomery Water Group 1995). In addition, the City of Port Townsend reports high concentrations in their Sparling well before treatment is performed (Jablonski 2000 personal communication).

3.2.4 Confirmed and/or Suspected Groundwater Contamination Sites

A review of confirmed and/or suspected groundwater contamination sites was performed based on lists of hazardous sites, contaminated sites, and leaky underground storage tanks. These lists are updated regularly by Ecology and presented to the public on the Internet. Table 3-7 summarizes the cases of groundwater contamination compiled from the lists, all of which occur within Jefferson County. Seven hazardous/contaminated sites were listed: three confirmed cases at the U.S. Navy installation on Indian Island, one confirmed case in Port Townsend, two suspected cases in Port Townsend, and one suspected case in Quilcene. A wide range of groundwater contaminants were reported, including heavy metals, halogenated organics, non-halogenated solvents, PCB's, pesticides, petroleum products, and other unspecified organic matter.

Thirteen sites were listed where leaking underground storage tanks have contaminated groundwater. The sites occur in Port Townsend, Nordland, Chimacum, Port Ludlow, and Quilcene. Underground storage tanks typically contain petroleum products, although tank contents are not presented on the list.

None of the lists specify whether cases of groundwater contamination have affected actual drinking water supplies. In April, 1999 Ecology and WDOH issued a joint report on groundwater contamination affecting drinking water. None of the sites presented on Table 3-7 were discussed in this report. The report did note that Ecology detected gasoline in private domestic wells in Quilcene. Ecology first provided bottled water, then tanked in water. About a year after the contamination was first detected in the wells, the homeowners began using their wells again. The water was tested and found to be free of petroleum products. No source of gasoline contamination was ever discovered.

3.2.5 Sub-Basin Groundwater Quality

The geographic distribution of elevated chloride and nitrate concentrations was evaluated for the eleven sub-basins in WRIA 17. Exhibits 4 and 5 present sub-basin maps of chloride and nitrate concentrations

(respectively) from the compiled water quality database. The symbols used in these figures allow differentiation of measured concentrations (by size), and well depths (by color). Where multiple samples were available from mapped wells, the available data were averaged. Iron and manganese are not discussed on a sub-basin basis because they are ubiquitous to the WRIA. Cases of anthropogenic groundwater contamination are also discussed for each sub-basin.

Table 3-7 Groundwater Contamination from Known and/or Suspected Contamination Sites in WRIA 17

Site Name	Site Location	Site Status	Rank	Groundwater Contaminants	Status of Contamination
USN Port Hadlock	Indian Island, Port Hadlock	Remedial action in progress.	0	Halogenated organics, metals, PCB's, pesticides, and other unspecified organic matter.	Confirmed
USN Port Hadlock Area 10 and 21	Indian Island, Port Hadlock	Construction completed, operation and maintenance underway.	0	Halogenated organics, metals, and other unspecified organic matter.	Confirmed
USN Port Hadlock Area 12	Indian Island, Port Hadlock	Construction completed, operation and maintenance underway.	0	Metals	Confirmed
Chevron Bulk Plant	Water St, Port Townsend	Independent Remedial Action: release report received, awaiting assessment by PLP.	1	Metals and petroleum products	Confirmed
Patterson Automotive	307 10th St, Port Townsend	Awaiting Site Hazard Assessment		Halogenated organics, metals, petroleum products, and non-halogenated solvents.	Suspected
Port Townsend Texaco	431 Water St, Port Townsend	Ranked, awaiting remedial action	2	Petroleum Products	Suspected
Olympic Testing Lab	Center Rd, Quilcene	Ranked, awaiting remedial action	2	Metals	Suspected

Data from Washington Department of Ecology Confirmed and Suspected Contaminated Sites Report, dated November 29, 1999 (Ecology 1999b).

Table 3-8 Groundwater Contamination from Leaking Underground Storage Tanks in WRIA 17

Site Name	Site Location	Site Status
Chimacum School District #49	91 W Valley Rd, Chimacum	Cleanup started
Nordland Grocery	5180 Flagler Rd, Nordland	Reported cleaned up, monitoring
Port Ludlow Golf Course	181 Cameron Dr, Port Ludlow	Cleanup started
Harper Oil Co.	2611 Sims Way, Port Townsend	Reported cleaned up
Port Townsend Lumber Company Inc	2219 Sims Way, Port Townsend	Awaiting cleanup
Port Townsend Paper Corporation	100 Paper Mill Rd, Port Townsend	Cleanup started, monitoring
Chevron 65735389	810 Water St, Port Townsend	Cleanup started, monitoring
Quilcene Grocery	14963 Center Rd, Quilcene	Cleanup started
Sandy's Chevron	294752 Hwy 101, Quilcene	Monitoring
Jefferson County Quilcene Shop Site	101 Rodgers Street, Quilcene	Cleanup started
Village General Store	293543 Hwy 101, Quilcene	Reported cleaned up
Quilcene Fish Hatchery	281 Fish Hatchery Road, Quilcene	Reported cleaned up

Data from Washington Department of Ecology, Leaking Underground Storage Tank List (LUST List) dated March 22, 2000 (Ecology 2000a).

4. WATER QUANTITY

The purpose of the water quantity assessment is to describe the general status and overall conditions of surface water and groundwater quantity and use in WRIA 17. The assessment focuses on assembling and reviewing existing information on groundwater and surface water quantity, precipitation, water demand, allocated water (rights, claims and applications) and potential effects of land use. This assessment also includes new data and analysis of potential groundwater recharge areas, areas of potential hydraulic continuity, and a preliminary water budget.

This assessment summarizes and presents information on water quantity and use throughout WRIA 17 and includes tabulation of existing data, analysis of potential trends, and plotting of data and model results on GIS based maps. Sub-basin specific discussions of specific water quantity and use are provided, as are identification of potential data gaps and recommendations for further study. Refer to Chapter 8-17 of this assessment for a focused description of water quantity and use for each of the 10 sub-basins in the WRIA.

Information sources for this assessment are primarily public databases, existing GIS coverages, and published documents. Databases used for the groundwater assessment include Ecology's water rights database (WRATS), the DOH public water system database, and well log databases maintained by Jefferson and Clallam counties. GIS coverages of surficial geology, soil types, and zoning were also obtained from Jefferson and Clallam Counties. Documents reviewed included water system plans, geologic maps, and regional and local hydrogeologic characterizations. The hydrogeologic studies were performed by state and federal agencies and by consultants. In addition, journal articles were reviewed regarding relationships between land use and groundwater recharge. The information used for various portions of the groundwater assessment is documented in each relevant section.

Information used for the precipitation assessment included publicly available weather station data and a contour map of annual precipitation published by federal agencies. Surface water information included flow data from USGS and other sources, as well as published reports.

4.1 WATER QUANTITY IN WRIA 17

4.1.1 Groundwater Quantity and Recharge

Groundwater quantity is defined, for the purpose of this report, as the annual amount of water recharging the groundwater flow system. Recharge originates on the land surface from rainfall percolating into soils. This water passes through the root zone, where it is either taken up by plants or continues downward toward underlying aquifers. In some cases, low permeability glacial till immediately underlies the root zone and causes infiltrated water to accumulate in a shallow, "perched" condition. Perched groundwater slowly percolates downwards through the till (at a rate controlled by the till's permeability) and can also flow along the top of the till in a downslope direction. In some cases, perched water collected over the till will reach the land surface and cause runoff during storm flow events. Recharge entering the groundwater flow system flows towards discharge features. Groundwater may discharge to springs, streams, marine bodies, wetlands, ponds, and wells. A portion of the groundwater recharge maintains baseflow in streams and springs, saturation in wetlands, and controls the dynamic balance between freshwater and saltwater in coastal aquifers. A portion of groundwater recharge is also available for withdrawal from wells.

Evaluation of "groundwater quantity" did not include estimation of groundwater storage. The reason this evaluation placed emphasis on recharge rather than storage parallels considerations usually taken for

surface water. For example, if only the amount of water in the channel is counted at a given instant, there would be no way to know how much is available on a sustained basis. The same is true for groundwater. The so-called groundwater reservoir is dependent on continued refilling (recharge), as is a surface reservoir or river channel. While it is possible to roughly estimate the amount of water present (i.e., in storage) in the ground at a given instant, a more important consideration for the purposes of water supply (wells), or the dependence of streams on groundwater discharge (baseflow), is the rate of flow of water that is passing through the groundwater system. It should be noted that for both surface water and groundwater, storage can provide an important source of peaking supply but cannot provide sustained supply.

This section presents the methods, assumptions, results, and limitations of recharge estimation for WRIA 17. The estimation approach is designed to provide reasonable, preliminary estimates of the spatial distribution and seasonal variation of groundwater recharge in the WRIA. It should be noted that, due to the inherent natural variability in the factors controlling recharge processes, estimated recharge values must be considered approximate. In most natural hydrologic systems, only a moderate degree of accuracy can be obtained in estimating recharge. The analysis presented herein is based on available data and accepted methods of recharge estimation. It is expected that as additional data become available, and additional supporting analyses are performed, estimates of recharge will be further refined and improved.

4.1.1.1 *Recharge Model Description and Estimation Methodology*

Recharge from the land surface was estimated with a combination of GIS analysis and a proprietary spreadsheet model developed by PGG (the "recharge model"). GIS analysis was used to characterize the spatial distribution of factors that significantly influence the recharge process. GIS coverage of precipitation was derived from the isohyetal analysis discussed in Section 2.2. GIS coverage of soil types, surficial geology, and zoning (to represent land cover) were obtained from Jefferson and Clallam Counties and simplified into smaller numbers of representative categories. From these GIS coverages, unique combinations of precipitation, soil type, land cover, and surficial geology were identified and assigned to individual "recharge classes." PGG's recharge model was run for 144 recharge classes, and predicted monthly/annual groundwater recharge was saved to a computer file. Recharge prediction for a variety of other recharge classes were obtained by linear combination of the modeled recharge classes. GIS was used to plot the predicted annual recharge for each recharge class and calculate recharge statistics for each sub-basin.

PGG's recharge model is based on the algorithms used in the "Deep Percolation Model" developed by the USGS (Bauer 1996; Bauer and Vaccaro 1987). The model was run based on average monthly values of precipitation and ambient temperature as well as information regarding plant water demand, soil hydraulic properties, and permeability/depth of till (where present). It employs a daily water budget to account for soil moisture, perched conditions over till, evapotranspiraton and runoff. The model tracks incident precipitation through the soil profile, divided into a series of six-inch soil layers, down to a depth of five feet (or to a till layer, whichever is shallower). For each day, a constant portion of the monthly precipitation is allowed to infiltrate into the topmost soil layer. If the soil moisture capacity is below field capacity, the precipitation is allowed to fill the soil layer to field capacity. If any infiltrated water remains, it is allowed to pass into the next soil layer and fill that layer to field capacity. This process is repeated downward through the soil profile. On a daily basis, water is removed from the soil layers that contain the root zone by dividing potential evapotranspiration evenly between soil layers and calculating actual evapotranspiration as a function of soil texture and available moisture. Daily potential evapotranspiration is estimated using the Blaney-Criddle method (SCS 1970). Recharge is defined as the flow rate of water moving through the bottom soil layer. If a till layer is modeled, recharge passes through the till as directly proportional to the till permeability and the hydraulic gradient across the layer

(assuming perched conditions over till). If saturation above the till reaches the land surface, precipitation unable to enter the (already saturated) soil is modeled as runoff.

4.1.1.2 *Model Assumptions*

A number of assumptions enabled application of the recharge model to the range of conditions observed in WRIA 17 and ensured that representative values of hydrologic parameters were used where measured data were unavailable. These assumptions, and how they were applied to the estimate recharge, are listed below.

1. Precipitation over the WRIA was divided into 10 isohyetal "bands", as shown on Exhibit 2 in Appendix A. The bands have representative precipitation values of 15, 20, 25, 30, 35, 40, 50, 60, 70 and 80 in/yr. The seasonality of precipitation within each band is assumed to be closely approximated by the monthly percent of annual precipitation observed in nearby climatic monitoring stations (as shown on Figure 2-5). For each annual precipitation band, the monthly percent of annual precipitation was interpolated between climatic monitoring stations with neighboring annual values. For representative precipitation bands located outside the range of values observed at monitoring stations (e.g. 15, 60, 70 and 80 in/yr), monthly percentages were taken from the weather station with the closest average annual precipitation. Monthly temperatures for all lowland areas of the WRIA were assumed equal to the average values between Port Townsend and Quilcene stations. The average monthly temperature was typically within ±6 percent of Port Townsend and Quilcene values.

2. Available water capacity (AWC), the hydraulic soil parameter that controls soil storage and the availability of water to plants, was modeled using four representative values. There are 130 state soil codes documented in WRIA 17, with AWC values ranging from 0.03 to 0.40 and some variability among horizons within the soil profile. For WRIA 17, the model generalizes AWC by assigning each soil type a value of either 0.05, 0.11. 0.18 or 0.35 based on its depth-averaged characteristics. In addition, the representative AWC value is assumed uniform over the soil profile.

3. Digital coverage of surficial geology in the WRIA was generalized into three representative classes. All categories of consolidated rock were grouped together as "bedrock". All categories of basal till were grouped together as "till". All categories of unconsolidated sediments (e.g. outwash, alluvium, stratified glacial drift, lacustrine deposits, ablation till) were categorized as "outwash". All surficial geology classes in the outwash category, whether fine-grained or coarse grained, are distinguished by the absence of underlying till.

4. Where soil descriptions cite the occurrence of shallow till or bedrock, this occurrence was added to the generalized GIS coverage of surficial geology (if not already present).

5. Recharge to areas with shallow or exposed bedrock is controlled by the permeability of the bedrock. Although bedrock may contain locally high permeability fractures, its bulk permeability is generally low over a large area. Recharge to bedrock was assumed to occur at a representative permeability of 10^{-7} cm/sec. Assuming a unit gradient, this translates to 1.2 in/yr of recharge.

6. Recharge to areas with shallow or exposed till is controlled by the till permeability and hydraulic gradient across the till layer. Although till permeability may vary locally, a bulk permeability of 10^{-6} cm/sec was assumed along with a thickness of ten feet. The model is not very sensitive to till thickness, and the assumed bulk permeability translates to about 12 to 14 in/yr passing through the till as recharge.

7. Depth to till determines that maximum thickness of perched soil saturation, and is assumed to be three feet. Ponding is not explicitly modeled when saturation accumulated above the till reaches the land surface. Ponded water is assumed lost to runoff, and is assumed to be the only source of runoff. Loss of water through flow in the thin perched zone above the till was not modeled. (See additional description below.)

8. A number of "special conditions" are modeled with fixed recharge values. Recharge is assumed to be zero in bogs, marshes and beaches, which are treated as discharge areas in this modeling exercise. Recharge is assumed to be equivalent to precipitation in gravel mines. Recharge is assumed to equal 12 inches per year for surface water bodies, which are assumed to be perched upon till and therefore allow downward flow according to the permeability of the till. It should be noted that all of these special conditions combined represent less than one percent of the total WRIA area.

9. Over the large scale, land cover is assumed to be correlated with zoning classifications. Each zoning category in Clallam and Jefferson County was assigned into one of six land-cover categories based on percent grass cover, percent forest cover (coniferous trees), and estimated percent impervious cover. In all but a few predominantly paved areas, the presence of impervious cover was assumed to have no significant impact on recharge. (See additional description below)

10. Rooting depths were assumed to be 24 inches for grass and 36 inches for coniferous trees, in accordance with assumptions used by the USGS in their Deep Percolation Model (Bauer 1996; Bauer and Vaccaro 1987). In addition, relationships between actual evapotranspiration and potential evapotranspiration were based on soil texture and soil moisture content in the same manner as the DPM (ibid).

PGG's recharge model allows specification of runoff as a fixed percentage of incident rainfall and as "rejected recharge" when precipitation falls on land where saturation over till has reached the land surface. In addition, the recharge model allows estimation of perched groundwater flow for saturation above till. In till covered areas, the combination of runoff and perched flow represents the portion of precipitation that is neither recharged or evapotranspired, but instead flows towards local streams. Runoff reaches streams relatively quickly, whereas perched flow may require hours, days or weeks to reach streams. Model calibration to stream hydrographs would be required to differentiate between these two sources of streamflow. For WRIA 17, these two components were lumped together into a single term for "rejected recharge". By setting perched flow equal to zero, all precipitation not taken up by plants or passing through till is forced to reach the land surface and run off when saturated soil storage is exceeded. Thus, rejected recharged is tracked via a surface route. Runoff was not modeled as a fixed percentage of precipitation, but was modeled only when saturation reached the land surface. Therefore zero runoff was simulated for outwash areas, where runoff was assumed to be negligible. Due to the WRIA-based scale of the analysis, the lack of extensive streamflow monitoring data, and the scope of this data summary, calibration of the recharge model to field observations of runoff was determined to be impractical.

It is important to recognize that a portion of the runoff generated as "rejected recharge" on till-covered areas flows downhill to outwash- or alluvium-covered areas, where it is able to infiltrate into the soil and supplement recharge occurring from incident precipitation. Infiltration may also occur where rejected recharge collects in till-covered swales or wetlands. The actual portion of rejected recharge from till-covered areas that supplements recharge in downgradient areas is unknown. Because of its potential role in supplementing primary recharge, rejected recharge was also accounted for in this recharge analysis. The presence and magnitude of rejected recharge indicates the possibility for supplemental recharge beyond that primarily derived from incident precipitation. No attempt is made to estimate values of supplemental recharge, nor are values of rejected recharge estimated for bedrock covered areas. Runoff

in bedrock-covered areas is expected to be relatively high, and is better estimated through analysis of surface water hydrology.

Zoning classifications (Exhibit 1) were generalized into six land-cover categories for the WRIA based on conversations with Jefferson and Clallam County planning staff (Lasorsa 2000 personal communication; Klein 2000). Planning staff were asked to estimate the percent of land covered by grass, coniferous forest, deciduous forest, barren, and impervious for each zoning class. Estimates for deciduous forest were very low, and were therefore disregarded. Based on the planners' descriptions, each zoning class was then generalized as either: all grass, all (coniferous) forest, 50 percent grass/50 percent forest, 25 percent grass/75 percent forest, 42.5 percent grass/42.5 percent forest, and zero recharge. Table 4-1 presents the zoning classes and PGG's recharge categories. In general, the presence of paved areas was assumed not to adversely effect groundwater recharge in areas of rural residential development. However, various commercial and industrial areas with 75 percent or more paved area were assigned values of zero recharge. In addition, a special category of 42.5 percent grass/42.5 percent forest was developed for the Port Townsend UGA. Approximately 15 percent of the UGA was assigned zero recharge to infer impervious surface areas where storm water is collected and discharged to marine water in downtown Port Townsend and Morgan Hill.

Table 4-1. Zoning Codes and Model Land-Cover Categories

Zoning Code	Description	County	PGG Category	Notes
CEN	Rural Center	Clallam	grass	mostly neighborhood
CF	Commercial Forest	Clallam	forest	
GC	General Commercial Zone	Clallam	zero	Diamond Point Airstrip
M	Industrial	Clallam	zero	
P	Public	Clallam	forest	mostly DNR lands
RC	Rural Commercial	Clallam	zero	hotel on W Sequim Bay Rd
RSC	Rural Suburban	Clallam	grass	Bell Hill
S(R-ll)	Sequim Urban Growth Residential II	Clallam	grass	Similar to RSC
URL	Urban Residential Low Density	Clallam	grass	
JAMESTOWN	Jamestown Indian Reservation	Clallam	zero	casino and tribal headquarters
R5	Rural low (5 acres)	Clallam	50 grass, 50 forest	forest land that has been mostly cut
R2	Rural (2 acres)	Clallam	50 grass, 50 forest	highly variable b/t forest and grass
R20	Rural very low (20 acres)	Clallam	forest	
SEQUIM	City of Sequim	Clallam	grass	
AG-20	Commercial Agriculture	Jefferson	grass	
AIRPORT	Airport Essential Public Facilities	Jefferson	grass	
CF	Commercial Forest	Jefferson	forest	
HI	Industrial -PT Mill	Jefferson	zero	
IF	Inholding Forest	Jefferson	forest	smallest forest land parcels, residences sometimes attached
L/C	Glen Cove Industrial Area - Light Industrial/Commercial	Jefferson	zero	
LI	Light Industrial	Jefferson	grass	
MILITARY	Military	Jefferson	forest	
MPR-MF	Master Planned Resort-Multiple Family 10:1	Jefferson	50 grass, 50 forest	Port Ludlow, not fully built out
MPR-OSR	Master Planned Resort-Open Space Reserve	Jefferson	forest	Port Ludlow
MPR-RA	Master Planned Resort – Recreation Area	Jefferson	grass	Port Ludlow Golf Course

Table 4-1. Zoning Codes and Model Land-Cover Categories (continued)

Zoning Code	Description	County	PGG Category	Notes
MPR-RC/CF	Master Planned Resort-Resort Complex/Community Facilities 10:1	Jefferson	50 grass, 50 forest	not yet built out to 10:1
MPR-SF	Master Planned Resort-Single Family 4:1	Jefferson	50 grass, 50 forest	
MPR-SFT	Master Planned Resort-Single Family Tracts 1:2.5	Jefferson	50 grass, 50 forest	
MPR-VC	Master Planned Resort-Village Commercial Center	Jefferson	zero	
NATIONAL FOREST	National Forest	Jefferson	forest	
NATIONAL REFUGE	Nation Refuge	Jefferson	grass	
P.T. UGA	Port Townsend Urban Growth Area	Jefferson	42.5 grass, 42.5 forest	see discussion in text
PARK	Parks, Preserves, Recreation	Jefferson	50 grass, 50 forest	includes golf course, boyscout camp, undeveloped golf course
RBIZ	Resource Based Industrial Zone	Jefferson	grass	old log mills, still operating
RF	Rural Forest	Jefferson	forest	
RR 1:10	Rural Residential 1:10	Jefferson	25 grass, 75 forest	
RR 1:20	Rural Residential 1:20	Jefferson	25 grass, 75 forest	
RR 1:5	Rural Residential 1:5	Jefferson	50 grass, 50 forest	involves smaller lots down to 1/2 acre
RURAL CENTER	Rural Village Center	Jefferson	grass	commercial areas e.g. Port Hadlock, no storm water system
UNKNOWN	Unknown	Jefferson	grass	
WASTE FACILITY	Waste Management Essential Public Facility	Jefferson	zero	transfer station

Source: Jefferson and Clallam Counties

4.1.1.3 *Model Limitations and Intended Uses*

Application of the recharge model to WRIA 17 is intended to provide reasonable estimates of recharge inflows; however, on the local scale, natural variation and parameter uncertainty dictate that recharge estimates be seen as approximate. The following points are intended to improve understanding of model limitations and how model results should be put to use given these limitations.

1. Estimates of recharge in areas where till permeability limits recharge rates will be highly sensitive to the assumed value of till permeability. Model estimates for recharge through till, ranging from 12 to 14 in/yr, show good agreement with numbers published in the literature. A recent USGS summary of 28 studies for which infiltration through till was estimated showed a range of 1.5 to 37.4 in/yr (Bauer and Mastin 1997). Those studies for which rigorous methods were employed showed a weighted average of 13.6 in/yr over a combined area of 251 square miles. Nevertheless, potential uncertainty in the modeled value of recharge through till must be acknowledged. Without additional information, it is reasonable to expect variability of till recharge in the range of ± 50 percent of the values predicted by the model. Thus, in areas where till permeability limits recharge, predicted values may span a similar range of uncertainty.

2. While the model was not directly applied in bedrock areas, fixed-rate estimates of recharge through bedrock will similarly be highly sensitive to the assumed value of bedrock permeability. It is acknowledged that estimated recharge to bedrock may vary greatly (by up to several orders of magnitude), and that the assumed value of 1.2 in/yr is considered to be conservatively low. Because

of the degree of uncertainty inherent in estimating recharge to bedrock, recharge estimates for sub-basins dominated by bedrock should be considered highly approximate.

3. Zoning categories are likely to provide only a rough indication of actual land cover characteristics. Areas are sure to exist where characteristics assumed for zoning categories do not accurately represent land cover. In such cases, for instance, recharge may be estimated for trees when grass is actually present. However based on current model assumptions, differences in predicted annual recharge rates between these categories of land cover are relatively small.

4. Because model parameters are selected and applied over the WRIA scale, variations in local conditions can cause local discrepancies between predicted and observed phenomena. For instance, local variations in till depth and till permeability can cause local runoff in areas where the model predicts runoff to be relatively insignificant (i.e. areas of relatively low precipitation). In addition, the model does not simulate conditions where/when soil moisture is controlled by the regional groundwater flow system rather than direct, local recharge processes (e.g. surface ponding due to spring discharge). Such local departures and variations are expected in a WRIA scale analysis.

5. The model employed specific assumptions about runoff processes. It did not attempt to explicitly model perched subflow and downgradient infiltration of rejected recharge, and is not calibrated to values of storm runoff. In most sub-basins, runoff data are unavailable. Sub-basins where data are available are largely covered by bedrock, and the recharge model was not directly applied to bedrock areas (rather a fixed rate of recharge was assumed). The model did not differentiate runoff behavior between areas of differing topographic relief and differing land covers (e.g. forest, pasture, lawns). The portion of the WRIA to which the model was applied excluded the bedrock dominated, steep slopes of the Olympic Mountain foothills. Surface-water runoff modeling in King and Snohomish counties suggests that runoff varies as a function of land cover, increasing from forest to pasture to urban/ suburban lawns (Beyerlein 1999). The degree to which these relationships can be directly applied to the more rural portions of WRIA 17 is unknown, however the simplification of lumping these land-cover categories together may cause some overestimation of recharge in non-forested areas. Model predictions of runoff are further discussed in the following section, and relationships to land cover are discussed in Section 4.5.

6. Uncertainties regarding till permeability, bedrock permeability, actual land cover, and runoff characteristics can be seen as data gaps. While reasonable assumptions were employed regarding these parameters, additional data collection and analysis might further improve recharge estimates. Recharge estimates through till are inherently variable and uncertain, but may be improved by calibration of groundwater flow models, surface-water runoff models, and/or balancing water budgets in areas where sufficient documentation of streamflow is available. Such modeling can only occur when sufficient data are collected and financial resources available. Bedrock recharge estimates may be similarly improved with modeling or with baseflow analyses from bedrock dominated watersheds. Improved definition of land-cover distributions may be attainable by using actual satellite data rather than zoning information. Finally, runoff assumptions could be further refined when stream gauging data are available for the lowland areas where the recharge model was applied or based on relationships observed from surface water modeling in nearby regions of the Puget Sound Lowland.

7. Methodological limitations arise from limitations in available knowledge and current research. For instance, although uptake of soil water by grass has been well characterized, available methods of estimating water consumption by coniferous forests in the Pacific Northwest are known to suffer from inaccuracies due to inability to adequately estimate interception losses during winter months. Interception loss is known to be particularly significant in northwest forests during wintertime, when

advective loss of intercepted moisture can dominate evapotranspiration (Bauer and Mastin 1997; Black 1999 personal communication). Current methods of ET estimation have not fully developed suitable means for estimating advective losses during winter months. Thus, estimates of recharge beneath coniferous forests prepared for this study must be seen as an approximation representing the best available information. In addition, information is just becoming available about the relationships between impervious surfaces and runoff characteristics in areas of low, rural residential development densities. More research in these areas, if appropriately applied, could improve the accuracy of recharge estimations in more developed portions of the WRIA.

8. Model predictions of recharge are considered to be adequate for water budget analysis and could also be used as input for a groundwater flow model. The predictions should be seen as initial estimates, inclusive of the uncertainties discussed above, and subject to further revision should additional water-budget or modeling results become available.

9. Model predictions of rejected recharge (runoff) should not be assumed entirely available for subsequent infiltration in downgradient locations. The portion of locally rejected recharge infiltrated downgradient is largely unknown. Disregarding infiltration of rejected recharge is the most conservative (i.e. underestimated) approach to handle this portion of the recharge process.

10. Recharge estimates should not be used to estimate groundwater availability for pumping withdrawals on either local or regional scales. On the local scale, aquifers may conduct significantly more groundwater than the amount of recharge estimated to occur over the small area surrounding a well. Upgradient recharge areas can be extensive relative to areas of local concern. On the regional scale, recharge inflow to the water budget should not be used as a direct measure of groundwater availability. Impacts associated with groundwater withdrawals (e.g. to stream baseflows or saltwater intrusion) can limit groundwater availability. Further discussion of the relationship between the water budget and determination of groundwater availability is presented in Section 4-3.

4.1.1.4 *Spatial Distribution of Recharge*

A map of estimated recharge over the entire WRIA is presented on Exhibit 6 (Appendix A) and recharge statistics are summarized in Table 4-2. Recharge is lowest in the extensive bedrock areas that occur in the western portion of the WRIA, and on the northern tip of the Miller Peninsula where rainfall is low (15 to 20 in/yr). Low-recharge areas also stand out in bedrock locations on the south end of Discovery Bay, near the head of Ludlow Bay, north of Quilcene Bay, and on Indian Island (among others). These areas all fall into the 0-5 in/yr recharge category. Just south of the northernmost tips of the Quimper and Miller peninsulas, recharge is predicted to increase into the 5 to 10 in/yr range. On the Miller Peninsula, this increase is due to higher modeled precipitation input. On the Quimper peninsula, the increase is likely due to changes in modeled land cover associated with zoning.

Most of the non-bedrock areas south of Discovery and Mats Mats Bay are predicted to receive between 10 to 15 in/yr of recharge. Despite the fact that precipitation increases in a south-southwesterly direction, recharge in most areas does not tend to increase beyond 10 to 15 in/yr. The limiting factor for these areas is the presence of shallow glacial till. Even where precipitation is plentiful, the recharge model allows till to pass only 12 to 14 inches/year. Further north, where precipitation (P) minus actual plant evapotranspiration (AET) is less than 12 in/yr, the permeability of the till ceases to become a limiting factor and recharge through till is equal to P-AET. In channelized features where there is no till, predicted recharge exceeds the 12 to 14 in/yr model limit. Predicted recharge to these alluvial and/or

Table 4-2. Recharge Estimates for WRIA 17

Sub Basin	Average Precip (in/yr)	Area (Acres)	Percent "Bedrock" Cover	Percent "Outwash" Cover	Percent "Till" Cover	Annual Recharge (af)	Annual Recharge (cfs)	Annual Recharge (in/yr)	Recharge as Percent of Precipitation	Annual Rejected Recharge (af)
Big Quilcene	51.9	51,509	92%	2%	5%	10,279	14.2	2.4	5%	3,653
Chimacum	27.2	23,681	5%	29%	62%	18,712	25.8	9.5	35%	846
Dabob-Thorndyke	39.3	33,116	2%	28%	67%	39,743	54.9	14.4	37%	11,985
Indian-Marrowstone	22.0	6,491	9%	7%	81%	3,002	4.1	5.5	25%	1
Little Quilcene	47.5	28,065	62%	8%	27%	14,652	20.2	6.3	13%	6,480
Ludlow	29.8	25,537	10%	17%	69%	21,237	29.3	10.0	33%	1,536
Miller	25.1	16,656	16%	6%	76%	8,115	11.2	5.8	23%	45
Quimper	21.5	18,514	5%	28%	61%	8,980	12.4	5.8	27%	2
Salmon-Snow	35.5	27,736	72%	7%	19%	9,461	13.1	4.1	12%	1,343
West Sequim Bay	28.2	24,136	76%	5%	18%	6,478	8.9	3.2	11%	65
WRIA 17 TOTAL	**---**	**255,441**	**---**	**---**	**---**	**140,659**	**194.3**	**6.6**	**---**	**25,956**

NOTE:

Sum of percent values for geologic cover categories may be slightly less than 100% due to polygon approximations used in the GIS analysis.

outwash channels reaches as high as 30 to 35 in/yr. These higher values reflect the fact that precipitation increases to values in excess of 50 in/yr whereas AET only increases from approximately 13 in/yr in the drier portions of the WRIA to about 20 in/yr in the wetter areas. Without till as a limiting factor, annual recharge (expressed as P-AET) can exceed 30 in/yr.

Higher recharge values are also noted along coastal areas of the Toandos Peninsula and surrounding Tarboo Bay. Similar to the outwash/alluvial channels noted inland, the till mantle is not present in these coastal locations. Recharge to these higher permeability features may also be supplemented by runoff (i.e. "rejected recharge" from the till). Exhibit 7 in Appendix A presents model predictions of rejected recharge for non-bedrock areas in WRIA 17. The model predicts that precipitation is insufficient to cause rejected recharge in the till-covered areas of the Miller and Quimper Peninsula. As precipitation increases to the south-southwest, predicted rejected recharge increase to values as high as 25 to 30 in/yr. A portion of the rejected recharge shown on Exhibit 7 is likely available to supplement recharge in adjacent outwash/alluvial channels and broad areas of permeable materials along the Toandos Coast. Where this occurs, the recharge values shown on Exhibit 6 will be locally elevated along the till-outwash contacts.

Recharge is known to be underestimated along coastal portions of the Bolton Peninsula. Exhibits 6 and 7 show bedrock in coastal areas, whereas shallow bedrock is only known to occur on the southern tip of the peninsula. As previously noted, GIS definition of surficial geology assumed that (in addition to geologic mapping) soil survey information accurately reflects the occurrence of till and bedrock. Where soil surveys indicated the presence of shallow till or bedrock, these geologic covers were added to the GIS analysis. The Jefferson County soil survey maps areas of "Beausite" soils along the Bolton coastline, and reports that these soils are underlain by sandstone conglomerate (SCS 1975). Thus, shallow bedrock was inaccurately mapped in these areas and recharge was limited to 1.2 in/yr, rather than values likely to range from 20 to 35 in/yr. However, given the limited geographic extent of these areas, the effects on recharge estimates on the sub-basin and WRIA scale are considered negligible.

Total recharge for the WRIA is estimated to be approximately 140,000 af/yr on an average annualized basis (Table 4-2). When distributed over the entire WRIA, this amounts to approximately 6.6 in/yr. This value contradicts the dominant recharge category of 10 to 15 in/yr shown on Exhibit 6, and reflects the fact that approximately 44 percent of the WRIA was modeled as bedrock. The average recharge rate for non-bedrock areas is estimated at 10.8 in/yr, and may be slightly higher due to infiltration of rejected recharge in higher permeability areas. Table 4-2 indicates that as much as 26,000 af/yr is predicted to be generated as rejected recharge from non-bedrock areas. No attempt was made to estimate what portion of this quantity enters local streams compared to the quantity that supplements recharge in neighboring areas.

While rejected recharge predicted by the model was not calibrated to streamflow hydrographs, the parameter was compared to estimates generated with the U.S. Environmental Protection Agency "HSPF" surface water model for representative conditions in more developed regions of the Puget Sound Lowland (Beyerlein 1999). Rejected recharge effectively represents a lumped combination of surface runoff and shallow perched flow over till. In comparison, HSPF allows estimation of both surface runoff and "shallow interflow". While the assumptions, algorithms and terms may differ between HSPF and the recharge model, the HSPF values derived for total runoff (surface runoff and shallow interflow) can reasonably be compared to the rejected recharge term. HSPF data were readily available for an annual precipitation rate of 40.7 in/yr (ibid). Figure 4-1 compares estimated of rejected recharge with the HSPF values for forest and pasture. Rejected recharge is plotted over the modeled range of soil moisture holding capacity and precipitation. This comparison suggests relatively good agreement between the modeling results, with some underestimation of runoff for pasture conditions. While HSPF modeling of

pasture land cover was based on reasonable assumptions, it has not been rigorously calibrated to watershed runoff data.

Discussion of estimated recharge for each sub-basin is presented in Chapters 8 through 17.

4.1.1.5 *Seasonality of Recharge and Groundwater Availability*

The seasonality of groundwater recharge is driven partly by the seasonality of precipitation, and partly by the tendency of till to accumulate and slowly release perched water. PGG's recharge model was used to estimate total monthly recharge for the variety of precipitation values, representative soil AWC values, and land cover encountered in the WRIA. Figure 4-2 shows predicted values of monthly recharge for a mixed land cover (50 percent grass/50 percent forest) overlying a soil of 0.11 AWC with no underlying till ("outwash" condition). Predicted recharge is displayed for annual precipitation values ranging from 20 to 60 in/yr. Figure 4-2 also shows predicted monthly recharge values for the same set of conditions, except that the surficial geology was modeled as "till". The following observations are readily apparent:

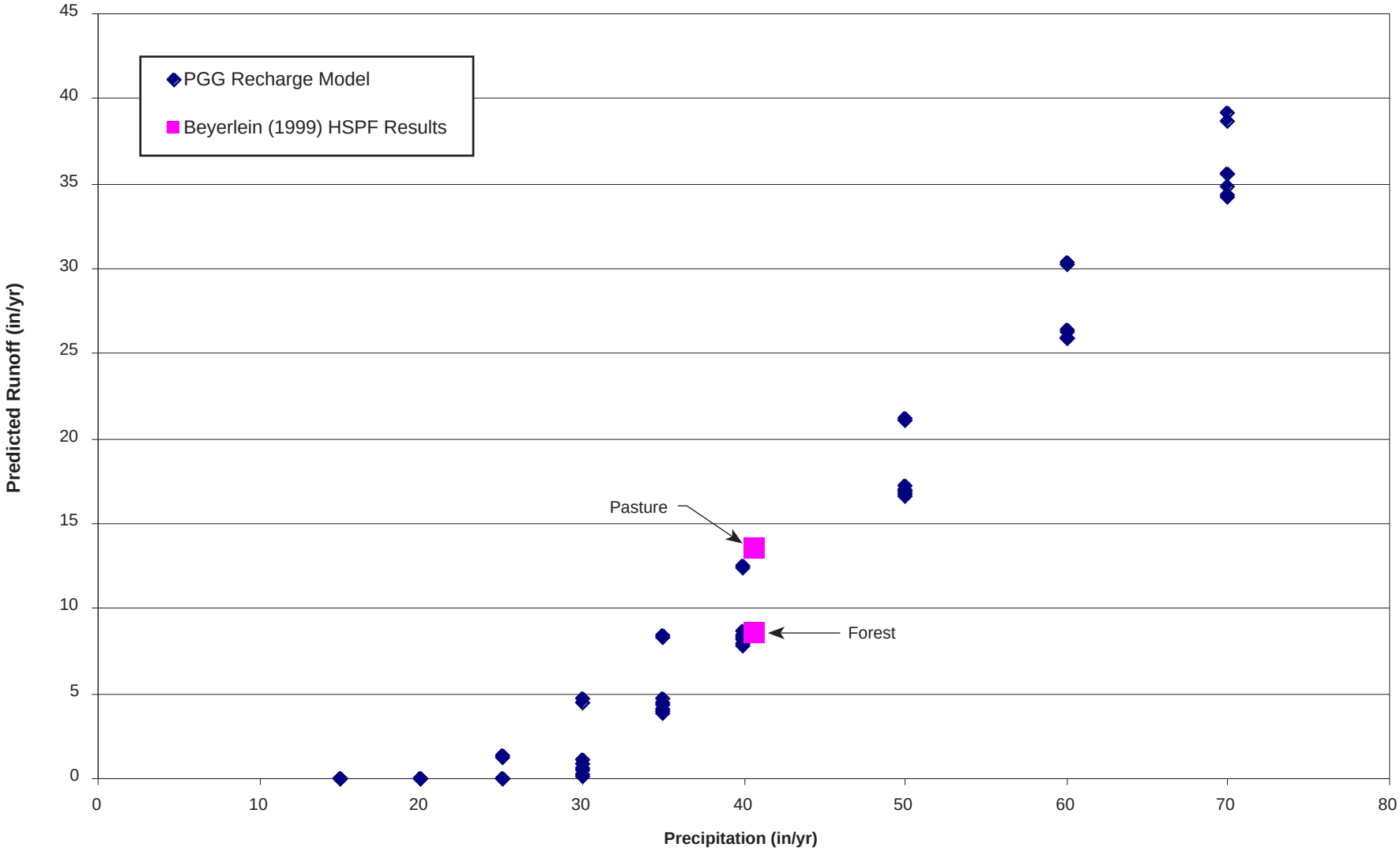
- Maximum monthly recharge for the outwash condition ranges from 2 to 10 in/month depending on the precipitation input. Maximum monthly recharge for the till condition ranges from 1.1 to 1.4 in/month, and is only slightly sensitive to the value of annual precipitation.

- Monthly recharge for the outwash condition is much more "flashy", with a large range of variation between the rainy season and the dry season. Recharge for the till condition is more constant, with less variation between seasons.

- Zero monthly recharge is observed for the outwash condition beginning as early as April or May, and ending as late as October. With the exception of the values for 20 in/yr precipitation, zero recharge for the till condition has a much shorter seasonal duration.

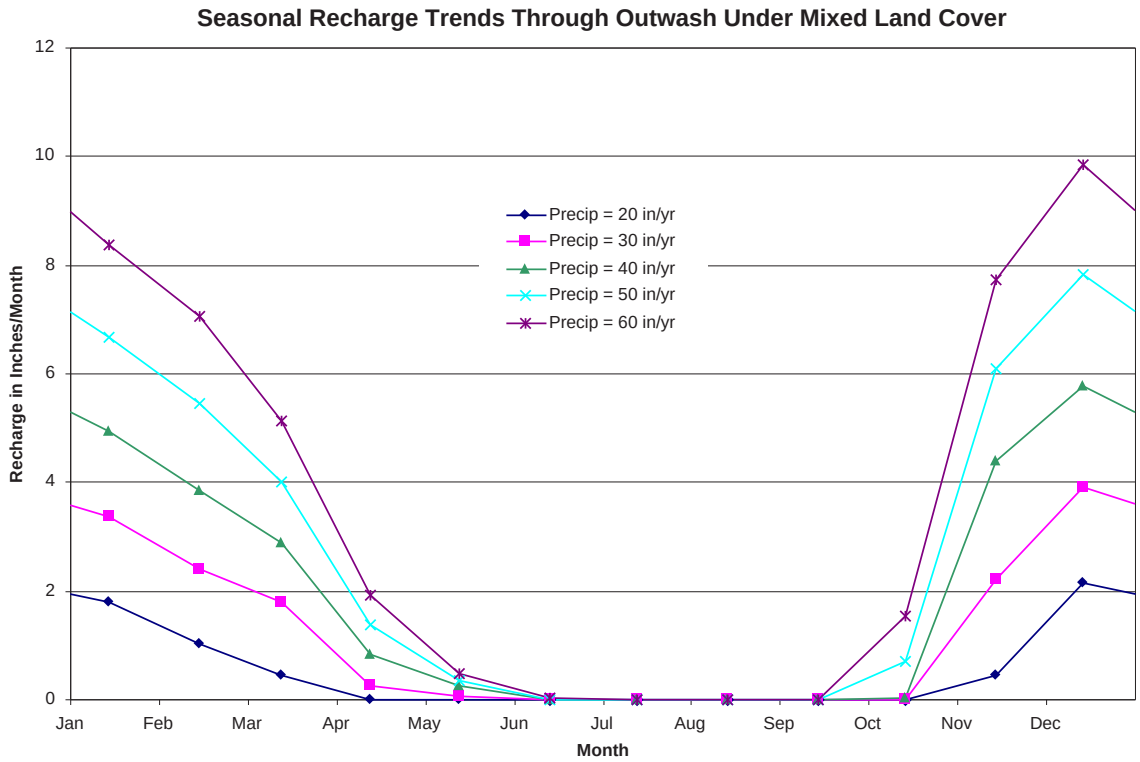
The difference in recharge seasonality between till and outwash conditions results entirely from the low permeability of the till restricting the downward flow of recharge. For the outwash condition, infiltrated rainfall not taken up by plants is predicted to continue downward through the soil and quickly reach shallow aquifers. During the winter months, plant AET is relatively low and precipitation is relatively high, thus accentuating winter recharge. For the till condition, infiltrated rainfall cannot continue downward and instead perches above the till. Water continues to seep downward through the till until the perched water is entirely exhausted in the latter portion of summer. The presence of perched water during summer months also makes water more available to plants, and plant AET is slightly higher for till conditions than for outwash conditions. For months when saturation over till reaches its maximum thickness (e.g. intersects land surface), the recharge model predicts that a portion of incident precipitation is lost to rejected recharge (runoff).

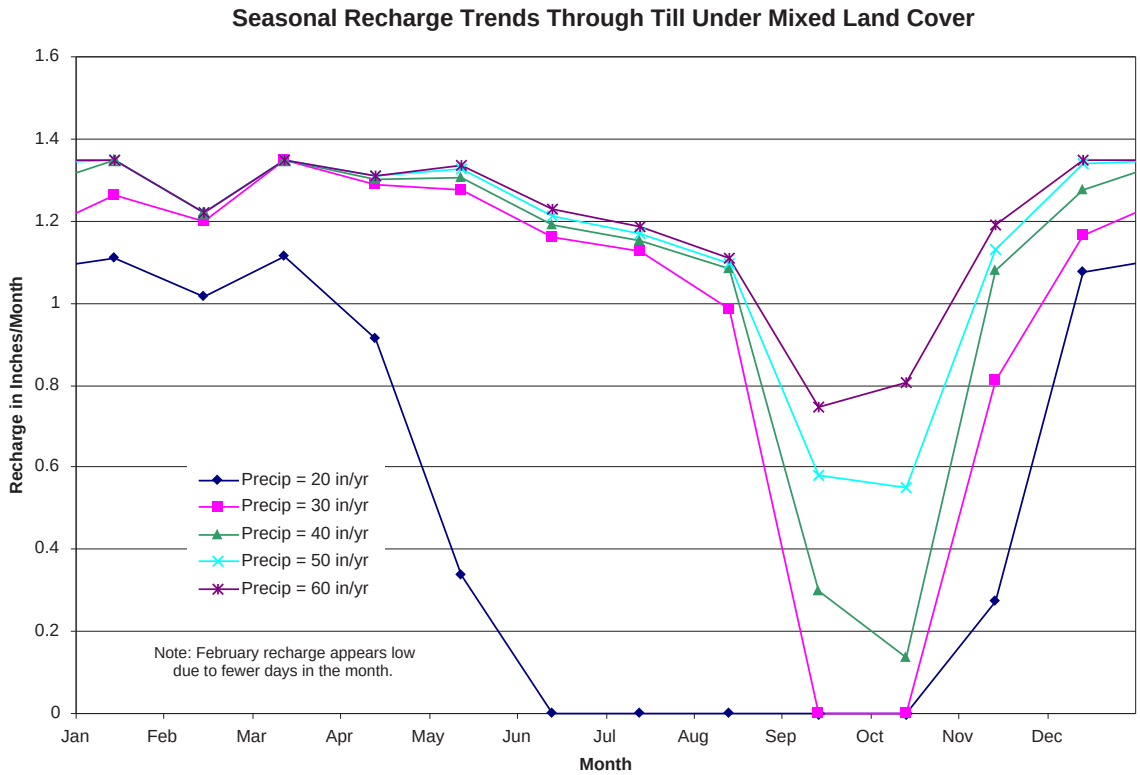
All other things being equal, these model results suggest that greater seasonal fluctuations in groundwater levels are likely to occur in non-till-covered areas than in till-covered areas. This may be the case in some areas, but this simple relationship is likely to be obscured by other factors in other areas. For instance, even where till is absent, the thickness and textural variability of the unsaturated zone between the land surface and the water table can effect the seasonality of the "recharge pulse". Greater distances and more textural layering will spread the pulse out more evenly over the year, and can significantly lag the arrival of the pulse to the water table. In addition, the water-level variations observed at any point in an aquifer



Note: PGG values span soil moisture AWC values between 0.05 and 0.35

Figure 4-1
Modeled Runoff as a Function of Precipitation





Source: PGG Recharge Model, 2000

Figure 4-2
Recharge Trends through Outwash and Till

can be influenced by variations occurring in other portions of the groundwater flow system. Such influences may alter the variations expected from overlying recharge conditions alone.

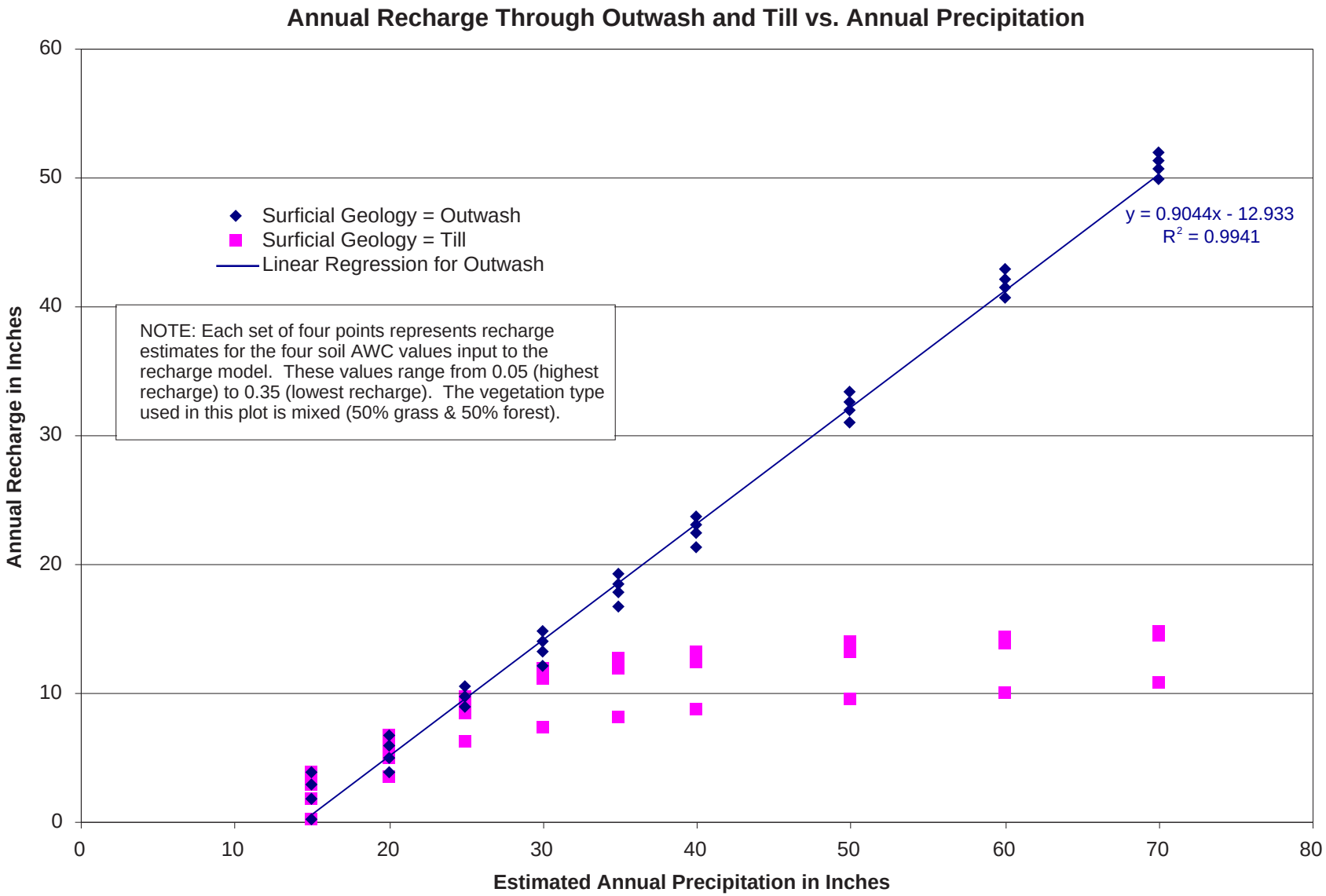
The seasonal availability of groundwater is generally much less variable than the seasonal availability of surface water. This is because aquifers tend to function as reservoirs, from which water can be withdrawn during periods of zero recharge to be replenished during the following recharge period. For this reason, the seasonality of recharge often bears little influence on the availability of groundwater. However in some cases, aquifer properties and the timing/magnitude of recharge inflow can combine in such a way that seasonal variation in aquifer saturation is significant. These "marginal" aquifers are less reliable for year round water supply, and more susceptible to the impacts of pumping. While most wells are unlikely to experience problems with seasonal variability of groundwater availability, such problems are occasionally reported. Areas with lower recharge are more likely to experience problems than areas with higher recharge. Beyond that generalization, the recharge model cannot be used to predict areas likely to experience seasonal difficulties with groundwater availability. Consideration of the local hydrogeologic framework is required to make such predictions; however, existing hydrogeologic characterization is insufficient in many areas of the WRIA to perform this analysis. Without further characterization, problem areas are often best identified through the reports of well owners.

4.1.1.6 *Long Term Recharge Trends*

Annual recharge varies as a function of annual precipitation. While many aquifers may function as groundwater reservoirs, extended periods of high or low precipitation may affect aquifer storage, reduce or increase groundwater discharge to streams and lakes, and alter groundwater availability for pumping withdrawals. Figure 2-10 presents plots of 5-year moving averages for precipitation at Olga, Chimacum, Port Townsend, and Quilcene. Evaluation of precipitation trends at Olga and Chimacum show periods when the five-year moving average varied from long-term averages of 28 and 30 in/yr by about 5 in/yr. For Port Townsend (average 19.5 in/yr), periods have occurred when the 5-year moving average fell as low as 12 to 15 in/yr. And for Quilcene (average 56 in/yr), one period occurred when the 5-year moving average dropped below 40 in/yr.

The sensitivity of groundwater recharge to variation in precipitation was evaluated by plotting recharge vs. precipitation for an assumed mixed land cover condition (50 percent grass/50 percent forest). Figure 4-3 shows estimated recharge plotted for till and "outwash" (till absent" conditions). Data points on the plot represent all four representative values of soil AWC, with lower values of AWC corresponding to higher values of recharge. Recharge predicted for "till-absent" conditions is highly sensitive to precipitation. The relationship between the two parameters can be characterized by a linear correlation with a correlation coefficient of 0.99. For every one-inch change in annual precipitation, annual recharge is predicted to change by about 0.9 inches. A similar direct relationship is observed for till-covered areas where annual precipitation is below 30 in/yr. Above 30 in/yr, the model predicts that recharge will be relatively insensitive to variations in precipitation. This is because 30 in/yr provides sufficient precipitation inflow to exceed the capacity of the till to pass water on an annual basis.

If a different permeability value were assumed for the till, the "cutoff" value for low sensitivity to precipitation would be different. Higher till permeability would allow more water to pass, and therefore have a higher precipitation cutoff value to define the point at which P-AET exceeds the capacity of the till to transmit water downward. Above this sensitivity cutoff, variations in precipitation are directly correlated to variations in rejected recharge (i.e. runoff). Below the cutoff value, runoff is fairly insensitive to variations in precipitation.



Source: PGG Recharge Model, 2000

Figure 4-3
Estimated Recharge for Till and Outwash

Approximately 75 percent of the non-bedrock covered portion of WRIA 17 is covered with till. Based on the model results using an assumed till permeability of 10^{-6} cm/sec, little impact is expected to recharge beneath till where drought precipitation remains above 30 in/yr. In locations with high precipitation, however, areas without till cover can represent a significant portion of the total recharge. Therefore, high precipitation areas with mixed till and non-till cover are not insensitive to drought. In low precipitation areas (i.e. <30 in/yr), model predictions suggest that the presence of a till offers no additional protection from drought.

While the relationship between precipitation and recharge can be predicted with the model, the sensitivity of various aquifers within the WRIA cannot be directly determined with the recharge model. In areas where the hydrogeologic framework is sufficiently characterized, average and drought distributions of recharge predicted with the recharge model could be used as input to a groundwater flow model to predict the impacts of drought. However, at the time of this assessment, few of the groundwater flow systems in WRIA 17 are sufficiently characterized to support development of a groundwater flow model. Hydrogeologic interpretation of well logs and water-level measurements would be required to adequately characterize these groundwater flow systems for model preparation. Development of groundwater flow models can be expensive, and should be performed only where outstanding questions warrant such an investment. In contrast, monitoring water levels in wells selected in a variety of aquifer systems can provide some indication of sensitivity to variations in both precipitation and recharge on both seasonal and long-term annual bases.

4.1.2 Surface Water Quantity

4.1.2.1 *Existing Hydrologic Data*

Several data sources were searched to identify stream gaging data available in WRIA 17 including the USGS and several local organizations. A list of stations and known data availability were compiled from those sources and sorted by type of data available and sub-basin. A list of stream gaging stations with known daily or monthly records is shown in Table 4-3. Daily or monthly records are typically the most useful data for water resource analyses and planning.

Several stations also exist with miscellaneous stream gage measurements available from the USGS. This data is compiled in Appendix B. Those stream gage records, being intermittent, are less useful for water resources analyses and planning.

A description of specific data sources is contained within the following paragraphs. Exhibit 1 shows the location of the stream gaging stations.

4.1.2.2 *United States Geological Survey*

The USGS began collecting stream flow data in WRIA 17 in 1927 on the Little Quilcene River. Although there are six USGS gaging stations listed in Table 3-3, only three are active (Big Quilcene River, USGS Gage No. 12052210; Little Quilcene River, USGS Gage No. 12051900; and USGS Gage No. 12052390). Selected hydrologic data collected by the USGS can be downloaded from a USGS website through the Internet at the following URL: http://water.usgs.gov/. Selected real time gages can also be accessed at the USGS, which provide provisional data in 15-minute intervals for the previous week. Historical records of daily streamflow and peak flows are accessed through the National Water Information System for many USGS stations. Many of these records date back 20 years or more, and are

Table 4-3. Stream Gaging Stations within WRIA 17 with Daily or Monthly Records

Agency	Station No.	Name/Location	Drainage Area (sq mi)	Data Type	Period of Record	Sub-Basin
USGS	12050500	Snow Creek near Maynard	11.2	Daily Flow	1952 to 1972 1977 to 1984	Snow Creek
USGS	12051500	Chimacum Creek near Chimacum	13.8	Monthly and Peak Flow	1952 to 1957	Chimacum Creek
USGS	12052210	Big Quilcene River below diversion	49.4	Daily Flow	1994 to present	Big Quilcene
USGS	12052500	Big Quilcene River near Quilcene	66.5	Daily Flow	1951 1971-1972	Big Quilcene
USGS	12052000	Little Quilcene River near Quilcene	23.7	Daily Flow	1926 to 1927 1951 1971 to 1972	Little Quilcene
USGS	12052400	Penny Creek	6.8	Daily Flow	1986 to 1987	Little Quilcene
USGS	12051900	Little Quilcene River at diversion	10.6	Daily Flow[1]	1994 to present	Little Quilcene
USGS	12052390	Big Quilcene River at Hatchery	~ 66	Daily Flow[2]	1994 to present	Big Quilcene
City of Port Townsend		Chimacum Creek	30.4	Daily Flow	1998 to present	Chimacum Creek

[1] Flows measured once daily. Rating curve available for flows less than 185 cfs.

[2] Once a day reading by USFWS.

verified up through water year 1997. Provisional water year 1998 and 1999 data are available by contacting the local USGS public information officer.

A list of discontinued surface water discharge stations and their period of record are published in the Water Resources Data – Washington Water Year 1998, annual water data report produced by the USGS. The daily discharge data for discontinued gages are available on Hydrodata databases. Hydrodata USGS Daily Values West 2 is available on CD-ROM at the University of Washington library network or by purchasing a CD from Hydrodata. Miscellaneous gage data of intermittent or temporary stations are also published by the USGS, and are included in Appendix B.

4.1.2.3 *Other Data Sources*

Organizations that have collected hydrologic data in WRIA 17 include the City of Port Townsend and the JCCD. The City has collected streamflow data on Chimacum Creek beginning in 1998 and the JCCD has assisted in those efforts. The City also collects streamflow data at their diversion dam on the Little Quilcene River. The JCCD is currently collecting streamflow data on the East and West forks of Chimacum Creek, Salmon Creek, Tarboo Creek, and Donovan Creek. WDFW operates a gaging station on Snow Creek.

Specific stream flow and surface water quantity information for each sub-basin is presented in Sections 8 through 17 of this data summary.

4.2 WATER ALLOCATIONS AND USE IN WRIA 17

The State of Washington regulates groundwater and surface water withdrawals through a legal system of water allocations. Water withdrawals for all but limited, small groundwater uses must be registered with Ecology. Upon receiving an application for a water right, Ecology may issue a permit to develop the

water resource. Water right certificates are issued after the water withdrawal has been perfected (actually put to use). In this assessment, permits and certificates are collectively referred to as water rights. Water rights have been required by existing water laws since 1917 (for surface water) and 1945 (for groundwater). Not all uses of water developed before these dates were registered as part of the water-rights process. In order to protect active withdrawals developed prior to these two dates, the State allowed individuals to register withdrawals during two "claims periods" – one between 1969-1974 and another between 1997 and 1998. A water-right claim is not an authorization to use water, but rather a statement in claim to a water withdrawal developed prior to 1917 or 1945. In most cases, the validity of existing claims has yet to be determined. Tribal water rights are unquantified, and are senior to all existing water rights.

Quantities of water allocations are not necessarily equal to quantities of water use. Allocations state legally permissible quantities of withdrawal. In many cases, the full extent of these permissible quantities has not been perfected, and a significant discrepancy exists between allocations and use. A distinction between allocation and use must be drawn in assessing the stress on the hydrologic system due to withdrawals. Actual use cannot be enumerated through water allocation statistics, but must be arrived upon by surveying the major water users and estimating the sum of minor users. Although total allocation may differ from actual use, total allocation is a significant figure because it represents the maximum legally permissible withdrawal from the hydrologic system.

Water resource allocations in WRIA 17 were evaluated based on quantity, geographic distribution, and purpose of use. For water rights, claims, and applications, allocated quantities were summed up for each square-mile "section" of the public land survey. Maps were constructed to portray geographic distributions, and quantities and statistics were calculated for each sub-basin and for the entire WRIA. Water rights, claims, and applications were also categorized by purpose of use. For each sub-basin, quantities were sorted by purpose to indicate the dominant types of allocated water use. Calculation of quantities and statistics was generally limited to "consumptive" allocations; however, "non-consumptive" allocations such as power, fish propagation, wildlife, and recreation (i.e. where the water is left in the stream) were also separately accounted.

Water rights are issued with permissible quantities of instantaneous and annual withdrawals. The instantaneous allocation (Qi) represents the capacity of the system to divert/withdraw water from the source. Qi's are expressed in cubic feet per second (cfs) for surface water and gallons per minute (gpm) for groundwater. The annual allocation (Qa) represents the maximum amount of water allowed over a year's time for a specified use (s), and is expressed in af/yr. Research of water rights records indicates that for most permits/certificates, the Qa is not withdrawn continuously but is taken seasonally or sporadically at instantaneous rates approaching the Qi. In this assessment, surface water rights were evaluated for Qa and Qi. Both of these quantities are significant, since Qi represents the instantaneous decrease in streamflow associated with a given diversion and Qa represents the total amount of water removed from the flow system. Evaluation of groundwater rights was based entirely on Qa because Qi's reveal little more than the pumping capacity of an individual well. By virtue of storing groundwater, aquifers tend to "average out" the impacts of instantaneous withdrawals taken sporadically over time. Seasonal variations in average pumping withdrawals, however, can cause seasonal variations to effects on the groundwater flow system. Evaluation of applications was limited to Qi, because applications do not typically list Qa values.

A special type of water resource allocation is the "exempt" water right associated with domestic dwellings. All domestic dwellings with a well are legally entitled to withdraw up to 5,000 gallons per day (5.6 af/yr Qa) for domestic use and irrigation of up to one-half acre. The allocation associated with exempt wells at the maximum allowable rate of withdrawal is potentially very significant. However,

most exempt wells are likely to be used for single domestic dwellings, and the actual amount of use associated with such an allocation is likely to be far below the maximum allowable use. Relative to the non-exempt water rights maintained in Ecology's WRATS database, exempt water rights provide an extremely poor indication of actual water use. For each sub-basin, exempt water rights were not included in the analysis of total allocation. However, the number of wells was used to provide a rough indication of the maximum exempt allocation that may be associated with private wells.

Another special type of water resource allocation, currently not present in WRIA 17, is water rights established by the Instream Resource Protection Program (IRPP). Commonly referred to as "instream flow requirements", their intent is to retain baseflow in perennial streams, rivers and lakes at levels necessary to protect wildlife, fish, scenic, anesthetic, recreation, environmental and navigation values. After the establishment of instream flow requirements, all new consumptive allocations are subject to instream flows being met, and no new groundwater or surface-water rights are granted that would conflict with instream flows or closures established by WAC. Water rights already in existence at the time instream flow requirements are enacted are not affected.

Water use in WRIA 17 was estimated based on readily available data. Groundwater use was estimated for each square-mile section in the WRIA, and statistics were calculated for each sub-basin and the entire WRIA. Reasonably good estimates of groundwater use could be derived for domestic single, domestic multiple and commercial purposes; however, actual data representing irrigation with groundwater sources could not be readily obtained. Agricultural groundwater use was therefore estimated based on water rights and claims and is considered to be "lower quality" data. The only surface water municipal user in WRIA 17, the City of Port Townsend, diverts surface water from the Big and Little Quilcene Rivers. Actual reports of surface water use in the WRIA were limited to these diversions. No attempt was made to characterize surface water use for domestic or irrigation practices because the available data are entirely limited to allocation information.

4.2.1 Data Sources and Data Reduction

Water rights data for WRIA 17 were obtained from Ecology's WRATS (Water Rights Application Tracking System) database. The data were reduced using the following procedures:

- Denied applications, rejected claims, canceled permits and duplicate records were removed from consideration;
- Water right changes were applied to the referenced records;
- Where annual allocations (Qa's) were not listed for permits, these quantities were obtained directly from Ecology;
- Where instantaneous allocation (Qi) or annual allocations (Qa) quantities were missing but irrigated acres or numbers of domestic units were specified, Qi's and/or Qa's were estimated based on multipliers recommended by Ecology;
- Water rights specified as non-consumptive were removed from the main database, and treated separately in the allocation analysis;
- Large allocations for fish propagation not specified as consumptive or non-consumptive were identified in the Big Quilcene sub-basin and marked as non-consumptive; and

- Water rights with multiple sources in more than one section were split into as many records as their were sections, and the allocated quantity was assumed split evenly between sources.

The WRATS database does not contain Qa and/or Qi data for all rights and applications, and claims generally do not specify the quantities of water claimed. For surface water rights, Qi was always reported in WRIA 17, and Qa could sometimes be estimated based on stated numbers of irrigated acres or domestic units associated with a particular water system. For estimation of surface-water Qa, allocations per irrigated acre were assumed to be 2 af/yr based on values used by Ecology for other watershed assessments for western Washington. Allocations per domestic unit were assumed to be 0.5 af/yr (Qa) based on recent discussions with Ecology (Davidson, 2000). This value represents a rough upper-end quantity Ecology might assign to a municipal or domestic multiple system per hookup. Groundwater rights were evaluated based on Qa only, and all rights had reported values of Qa.

Claimed quantities for irrigation were also estimated using Ecology multipliers of 2 af/yr (Qa) and 0.02 cfs (Qi) per acre, similar to other watershed assessments. For surface water claims, Qa's and Qi's were not calculated for domestic use because most historically active domestic surface water sources are likely to have been converted to groundwater wells for health purposes. For groundwater claims, the total number of claims per section was counted, and a Qa value of 1 af/yr per dwelling (also used for other watershed assessments) can be applied to each claim to estimate domestic use.

Groundwater use was estimated from multiple sources, including:

- Directly reported pumping withdrawals, numbers of hookups, and use per domestic hookup from the water system plans of large purveyors;

- Directly reported numbers of hookups and populations served for public water systems (contained in the DOH DUANE database;

- Estimates of residential populations for Local Planning Areas (LPA's) from the Jefferson County Comprehensive Plan (Jefferson County 1998); and

- Counts of well logs per section obtained from well databases maintained by both Clallam and Jefferson County Health Departments.

For large purveyors, reported quantities of annual withdrawal were assumed evenly distributed among the groundwater wells included in the system (located to the nearest square-mile section)[1]. Withdrawal data from the larger purveyors were also used to estimate a value of water use per domestic hookup, which was ultimately applied to smaller public water systems and single family domestic wells. For public water systems in the WDOH database without reported use estimates, the reported number of residential hookups was multiplied by this calculated average use. A number of these public water systems list both residential and non-residential hookups. Where both are listed, non-residential hookups were translated to equivalent residential hookups using the following algorithm recommended by WDOH staff (Kropack 2000 personal communication).

[1] An exception was made for the Port Townsend Tri-Area system, where almost all of the pumping comes from the Sparling Wells at a single location.

- For systems with more than three non-residential hookups, these hookups were assumed to represent transient use (e.g. trailer parks, campgrounds) and assigned 25 percent the use of residential hookups.

- For systems with three or less non-residential hookups, these hookups were assumed to represent more regular use (e.g. stores, businesses, churches, schools) and were assigned the same use as a residential hookup.

For all sub-basins within Jefferson County, population data were used to estimate numbers of single family domestic wells. Consumption from single family domestic wells was estimated using the same per hookup use as public water systems. For sub-basins in Clallam County (e.g. Miller and West Sequim Bay), well log databases were used to estimate numbers of single family domestic wells in each sub-basin.

Surface water use was estimated from water system reports by the City of Port Townsend, which document its diversions from the Big and Little Quilcene Rivers.

4.2.2 Groundwater Allocations

Data in the WRATS database for water rights in WRIA 17 are relatively complete. Out of approximately 220 consumptive water rights[2], Qa is specified for 218 and could be calculated for one. Table 4-4 presents the consumptive water-right data for WRIA 17, and Exhibit 8 shows the geographic distribution of Qa summed by square-mile section. The annual allocation of groundwater rights for the WRIA totals 8,096 af/yr, with the majority of allocation occurring in the Chimacum and Quimper sub-basins, followed by the Miller and Ludlow sub-basins. Water right allocations for each sub-basin are described by quantity and by types of use in Chapters 8 through 17. One additional groundwater right, located in the Big Quilcene sub-basin was not included in this analysis. The water right has no specified Qa, a rather large Qi (750 gpm), and is allocated for the purpose of fish propagation to the USFWS. Depending on the observer, this water right may be considered consumptive or non-consumptive. The water is not returned to the aquifer but is returned to the stream.

[2] Because the water right database was reduced to allow multiple entries for each water right with sources in multiple sections, this number is only approximate. Only two water rights had sources in more than one section.

Table 4-4. Summary of Consumptive Groundwater Rights in WRIA 17

SUB BASIN	Count of Applics	Applics Sum of GPM	Count of Claims	Claims Sum of Qa-AF*	Count of Rights	Rights Sum of Qa-AF	Count of Well Logs	Maximum Estimated Exempt Qa - AF
Big Quilcene	2	2,020	112	90	17	712	589	3,301
Chimacum	3	745	158	348	22	2,124	1034	5,796
Dabob-Thorndkye	1	120	91	20	18	491	169	947
Indian-Marrowstone	-	-	207	164	11	42	361	2,024
Little Quilcene	3	569	144	88	10	70	601	3,369
Ludlow	6	473	311	864	47	1,407	488	2,733
Miller**	4	1,740	118	116	33	1,045	155	869
Quimper	4	460	80	84	38	1,817	611	3,426
Salmon-Snow	-	-	34	10	2	19	523	2,932
West Sequim Bay**	-	-	107	60	23	368	481	2,696
Total WRIA 17	**23**	**6,127**	**1,362**	**1,844**	**221**	**8,096**	**5012**	**28,092**

*Values for claims as annual quantities (Qa) reflect irrigated acreage estimates alone. Many claims failed to report irrigated acreage, and associated Qa data could not be estimated. Domestic use, associated with most all claims, is not reflected in the Qa numbers.

** Estimates of single family domestic wells, and associated exempt water right Qa's, are likely underestimated for the Miller and West Sequim Bay sub-basins where well counts were estimated from county well databases rather than population analyses.

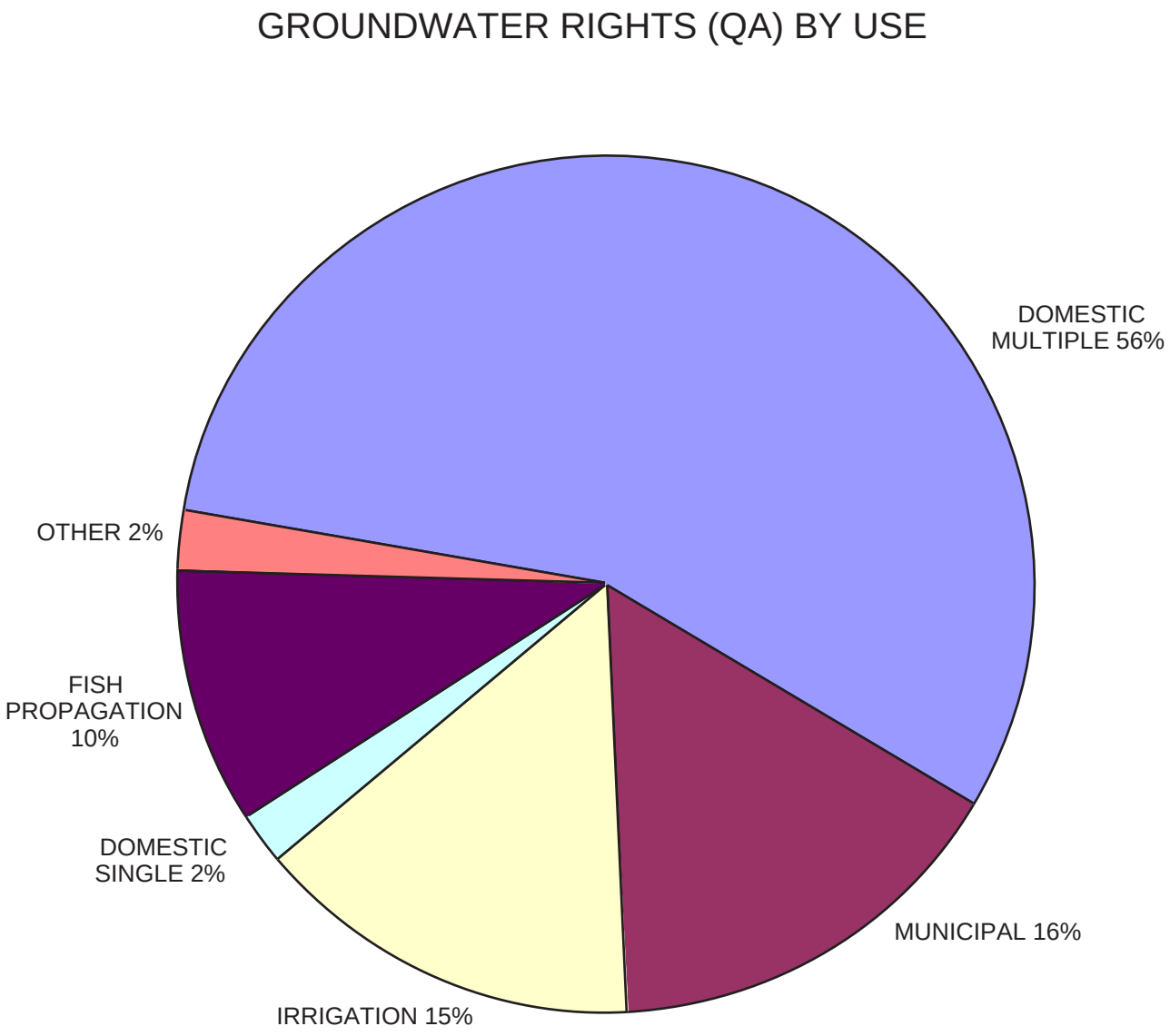
Note: Tribal water rights are unquantified and are senior to all existing water rights.

Exempt water rights could represent a rather large allocation in WRIA 17 if used to their full extent. Based largely on population estimates, there are over 5,000 single family domestic wells in WRIA 17 (see Section 4.3). This number of wells largely overshadows the number of water rights, thereby indicating that a large number of exempt domestic water rights are likely to exist. Assuming all 5,000 of these wells represented an exempt domestic water right, an additional 28,000 af/yr of groundwater would be allocated. In this case, consideration of exempt allocations would increase non-exempt allocations by about 350 percent. However, it was likely never Ecology's intent that domestic users would put their maximum permissible allocation to use. If a single household uses up to 500 gallons per day (rather than 5,000), the exempt allocation may represent something more like 2,8001,200 af/yr – or about 35 percent of current registered groundwater rights.

Figure 4-4 provides a breakdown of groundwater rights by purpose of use for all of WRIA 17. Not all of the water rights in the WRATS database are listed in the table of allocation by use. Thus, only 7,794 of the 8,096 are represented in this breakdown. The largest allocation in the WRIA is for domestic multiple use (56 percent), followed by municipal (16 percent), irrigation (15 percent), fish propagation (10 percent), and other purposes (4 percent). While the rights for fish propagation are listed as consumptive, a good portion of these withdrawals are likely returned to local streams.

There are 23 applications for groundwater rights in the WRIA. Requested Qi is listed for all 23 applications in the WRATS database, adding up to a total of 6,127 gpm. The WRATS database typically does not list values of Qa for applications, as Qa is generally negotiated during the permitting process. Table 4-5 provides a breakdown of the groundwater applications by use for each sub-basin and Exhibit 9 shows the geographic distribution of Qi summed by square-mile section. Although Qa data are unavailable, the requested Qi likely provides some indication of the magnitude of the proposed withdrawal. The largest applications occur in the Big Quilcene sub-basin (for fish propagation) and the Miller sub-basin (for domestic multiple combined with irrigation). Although applications are listed for multiple purposes, domestic multiple appears to represent the largest portion of the total application Qi, followed by fish propagation and irrigation (Table 4-5).

There are 1,362 groundwater claims in WRIA 17, situated in 208 different square-mile sections. Exhibit 10 presents the number of claims per section in the WRIA, and Table 4-6 lists the number of claims per sub-basin sorted by purpose of use. Purpose of use often includes multiple entries, among which domestic general, stock watering, and irrigation are most common. Among all 1,362 claims, 349 list irrigation as a purpose of use but only 119 list numbers of irrigated acres. Because only 35 percent of the claims for irrigation list numbers of irrigated acres, a representative estimate of the full amount of groundwater claimed for irrigation could not be obtained. Approximately 920 irrigated acres are listed by those claims stating acreage, which translates to 1,840 af/yr using Ecology's assumed value of 2 af/yr/acre. In addition, water claimed for domestic and stock use can be estimated based on Ecology's value of 1 af/yr per claim. Because the vast majority of claims list domestic or stock as a use, the total water claimed for domestic/stock is estimated to be approximately 1,362 af/yr. Adding the two numbers together, total claimed groundwater in WRIA 17 amounts to about 3,200 af/yr plus the unaccounted-for irrigation claims. While this represents at least an additional 40 percent of the "officially allocated" groundwater rights, the validity of these claims has not been determined.



Note: total allocation = 8096 af/yr, accounted by use = 7794 af/yr, domestic exempt wells = 28000 af/yr

Source: Ecology WRATs database

Figure 4-4
WRIA 17 Groundwater Rights and Use, Consumptive Use Only

4.2.3 Groundwater Allocation and Use

Groundwater use was estimated in WRIA 17 for domestic multiple, domestic single, irrigation, and commercial/industrial uses. Other uses, such as stock watering, fish propagation and mining were assumed to be insignificant relative to these four primary uses, and were not estimated. Municipal use in the WRIA is limited to surface water diversions from the Big and Little Quilcene Rivers. Estimates for groundwater withdrawals do not distinguish between consumptive and non-consumptive use. Instead, estimates are reported for the *total* amount of water pumped. Discussion of the non-consumptive portion of total pumping withdrawals is included at the end of this section.

Table 4-5. Groundwater Applications by Sub-Basin and Purpose of Use

Sub-basin	Purpose	Count of Applications	Total QI (gpm)
Big Quilcene	FR, DM	1	20
Big Quilcene	FS	1	2000
Chimacum	DM	1	45
Chimacum	IR	2	700
Dabob-Thorndkye	DM	1	120
Little Quilcene	FR, DM	1	250
Little Quilcene	IR	1	294
Little Quilcene	ST, DM	1	25
Ludlow	CI	1	60
Ludlow	DM	4	353
Ludlow	MI, DS	1	60
Miller	DM	2	700
Miller	IR, DM	1	1000
Miller	ST, IR, FS, DS	1	40
Quimper	DM	3	435
Quimper	IR	1	25
Total WRIA 17		**23**	**6127**

Explanation of Purpose Codes:

CI	Commercial and Industrial Manufacturing	FS	Fish Propagation
DM	Domestic Multiple	IR	Irrigation
DS	Domestic Single	MI	Mining
FR	Fire Protection	ST	Stock Watering

Table 4-6. Groundwater Claims by Sub-Basin and Purpose of Use

Sub-basin	Purpose	Count of Claims	Total Qi (Gpm)	Total Qa (af/yr)
Big Quilcene	not listed	6	-	0
Big Quilcene	DG	73	-	0
Big Quilcene	DG, IR	20	-	26
Big Quilcene	DG, ST	2	-	0
Big Quilcene	DG, ST, IR	7	-	2
Big Quilcene	IR	1	-	2
Big Quilcene	IR, CI, ST	1	100	20
Big Quilcene	IR, DG, CI, ST	2	300	40
Chimacum	not listed	10	-	10
Chimacum	DG	74	-	0
Chimacum	DG, IR	24	-	204
Chimacum	DG, ST	17	-	0
Chimacum	DG, ST, IR	25	-	132
Chimacum	IR	4	-	2
Chimacum	ST, IR	4	-	0
Dabob-Thorndkye	DG	64	-	2
Dabob-Thorndkye	DG, IR	13	-	10
Dabob-Thorndkye	DG, ST	4	-	0
Dabob-Thorndkye	DG, ST, IR	8	-	8
Dabob-Thorndkye	ST, IR	2	-	0
Indian-Marrowstone	DG	143	-	2
Indian-Marrowstone	DG, IR	33	-	74
Indian-Marrowstone	DG, ST	15	-	0
Indian-Marrowstone	DG, ST, IR	15	-	88
Indian-Marrowstone	ST	1	-	0
Little Quilcene	not listed	2	-	0
Little Quilcene	DG	88	-	0
Little Quilcene	DG, IR	22	-	26
Little Quilcene	DG, ST	15	-	0
Little Quilcene	DG, ST, IR	16	-	62
Little Quilcene	IR	1	-	0
Ludlow	not listed	2	-	0
Ludlow	DG	218	-	724
Ludlow	DG, IR	56	-	102
Ludlow	DG, ST	18	-	0
Ludlow	DG, ST, IR	8	-	36
Ludlow	IR	6	-	2
Ludlow	ST	2	-	0
Ludlow	ST, IR	1	-	0
Miller	DG	75	-	0
Miller	DG, IR	21	-	58
Miller	DG, ST	8	-	0
Miller	DG, ST, IR	12	-	56

Table 4-6. Groundwater Claims by Sub-Basin and Purpose of Use (continued)

Sub-basin	Purpose	Count of Claims	Total Qi (Gpm)	Total Qa (af/yr)
Miller	IR	2	-	2
Quimper	not listed	1	-	0
Quimper	DG	44	-	4
Quimper	DG, IR	18	-	50
Quimper	DG, ST	8	-	0
Quimper	DG. ST, IR	5	-	30
Quimper	IR	1	-	0
Quimper	ST, IR	3	-	0
Salmon-Snow	DG	19	-	0
Salmon-Snow	DG, IR	8	-	10
Salmon-Snow	DG, ST	1	-	0
Salmon-Snow	DG, ST, IR	6	-	0
West Sequim Bay	DG	72	-	0
West Sequim Bay	DG, IR	15	-	56
West Sequim Bay	DG, ST	12	-	0
West Sequim Bay	DG, ST, IR	5	-	0
West Sequim Bay	IR	2	-	4
West Sequim Bay	ST	1	-	0
Total WRIA 17		**1362**	**400**	**1844**

Explanation of Purpose Codes:

CI	Commercial and Industrial	IR	Irrigation
DG	Domestic General	ST	Stock Watering

Estimates of domestic single domestic, multiple domestic, and commercial groundwater use were considered to be relatively high quality. Direct reports of groundwater withdrawals and source locations were available from large purveyors, and account for about 40 percent of the residential and commercial groundwater use in the WRIA. These direct reports were also used to calculate average values of water used per residential hookup, and apply this value to hookups associated with other (smaller) public water systems and single family domestic wells. The numbers of hookups associated for public water systems for which direct reports were unavailable were obtained from the WDOH database, which also listed the locations of associated groundwater sources. The commercial portion of use for these public water systems was estimated by applying the algorithm described in Section 4.2.1 to any non-residential hookups. Based on this algorithm, and on directly reported data, total use from public water systems is calculated as combined commercial and residential use.

For all sub-basins located entirely in Jefferson County, groundwater use by single domestic wells was estimated by calculating the portion of the population not served by public water systems. Population estimates per sub-basin were derived from County population estimates, as described in Chapter 1. The populations served by public water systems were determined either by directly reported numbers or by multiplying numbers of hookups by 2.2 people per hookup. The number of single families dependent on surface water sources was assumed to be negligible. Populations served by single domestic wells were calculated by subtracting populations served by public water systems from total sub-basin populations. For the two sub-basins not entirely in Jefferson County (Miller and West Sequim Bay), numbers of well logs derived from county well databases were used to estimate single domestic groundwater use. These estimates are lower quality than population derived estimates, because the well log databases do not contain all currently active wells. Table 4-7 presents the results of the population analysis, and compares population-based estimates of single domestic wells with numbers of logs on file in county databases.

The analysis shows that, on average, the databases only account for about 35 percent of the population-based numbers of well logs and that considerable variability exists between sub-basins.

Table 4-7. Population Based Estimates of Single Family Domestic Wells

Sub-basin	Projected 2000 Population	Population for Public Systems with Reported Use	Hookups for Public Systems without Reported Use	Population for Public Systems without Reported Use	Logs in County Well Database	Population Required for Total Single Domestic Use	Wells Required for Total Single Domestic Use	Percent of Domestic Use Population Accounted for by Well Logs
Big Quilcene	1,428		60	132	83	1,296	589	14%
Chimacum	5,997	3,700	10	22	256	2,275	1,034	25%
Dabob-Thorndkye	448		63	139	169	309	141	120%
Indian-Marrowstone	874	60	9	20	259	794	361	72%
Little Quilcene	1,406		38	84	87	1,322	601	14%
Ludlow	3,580	2,258	113	249	442	1,073	488	91%
Miller	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Quimper	12,625	10,035	566	1,245	162	1,345	611	27%
Salmon-Snow	1,162		5	11	52	1,151	523	10%
West Sequim Bay	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total	**27,519**	**16,053**	**864**	**1,901**	**1,510**	**9,565**	**4,348**	**35%**

Source: Jefferson County, WRATS, and water system plans

n/a not available

Table 4-8 lists the reported values of total groundwater withdrawal and use per hookup obtained from the water system plans of large purveyors. The use values range from 120 to 287 gallons per day (gpd) per hookup. An average value for all the systems (weighted by numbers of hookups) was calculated to be about 180 gpd/hookup, including unaccounted water (i.e. leakage). This value is low relative to estimates for other surrounding counties. For example, hookups in Clallam County were estimated to use 272 gpd (Montgomery Water Group, 1999). In order to provide a representative range for domestic use, groundwater withdrawals were calculated using values of both 180 gpd/hookup and 250 gpd/hookup. These two rates were applied to all public water systems with more than one hookup and to all wells listed in the well databases. For the sake of conservative analysis, a value of 250 gpd/ft was used in all other portions of this report that consider groundwater use.

The estimates of groundwater withdrawals for public water systems are believed to accurately account for commercial and industrial (C and I) groundwater uses. Among the public water systems from which direct reports are available, the Tri-Area water system supplies groundwater for commercial-use to the Tri-Area; PUD No. 1 of Jefferson County supplies purchased surface water to commercial users in the Glen Cove area; and the Ludlow Water Company supplies groundwater to commercial users in the Port Ludlow area. A review of the WRATS database revealed twelve other C and I groundwater rights in the WRIA, however only four of these remain as potentially active users (Christensen 2000 personal communication). Two of these four water rights could be linked with known commercial enterprises and were listed in the WDOH public water system database. The other two could not be associated with known businesses, but were assumed also in the database if still actively used.

Table 4-8. Reported Groundwater Use from Water System Plans

System Name	Sub-Basin	Dominant Type of Use	Hookups	Period for Use Value	Total Use (af/yr)	Average Use Per Hookup (gpd)	Estimated Average Use Per Hookup w/o Leakage (gpd)	Total Groundwater Sources	Groundwater Use Per Source (af/yr)	Source
Sunshine Acres	Miller	Residential	205	1994	47.46	196	180	3	15.82	Polaris Engineering and Surveying (1995)
Kala Point	Quimper	Residential	460	1991	94.30	183		4	23.58	pers. comm., Christensen (2000)
Jefferson County Water District #1	Ludlow	Residential	191	1995	25.68	120		1	25.68	A.D.A. Engineering (1999)
Bridgehaven Water System	Ludlow	Residential	104	1996	33.45	287	not estimated	2	16.73	A.D.A. Engineering (1997)
Bywater Bay Water System	Ludlow	Residential	28	1993-95	8.78	280	not estimated	2	4.39	Parametrix Inc. (1997)
Gardiner System LUD #1	Miller	Residential	103		26.77	232	210	1	26.77	Parametrix Inc. (1997)
Glen Cove South	Quimper	Residential	70	1993-95	21.33	272	247	3	7.11	Parametrix Inc. (1997)
Ludlow Water Company	Ludlow	Residential	1062	historic	190.35	160	140.8	5	38.07	Montgomery Water Group (1995)
Ludlow Water Company	Ludlow	Commercial	35	historic	19.96	509	not estimated	5	3.99	Montgomery Water Group (1995)
City of Port Townsend (Tri-Area)	Chimacum	Mixed Residential and Commercial	1481	1999	523	275	200	3	not evenly distributed	Jablonski (2000 personal communication)
Sunshine Mobile and RV Park	Miller	Transient Multi-Unit	variable	1990-94	0.538			1	0.54	Polaris Engineering and Surveying (1995)
AVERAGE RESIDENTIAL						**179**	**161**			**(weighted based on numbers of hookups per system)**

NOTES:

Number of hookups based on WDOH database (2000 for Jefferson County and 1997 Clallam County) and data reduction algorithm described in text.

If a large discrepancy existed between the water system plan the hookups listed in the WDOH database, water system plan data were used.

In most cases, total use has been adjusted to the number of hookups reported in the WDOH databases (with data reduction algorithm applied).

Estimates of groundwater withdrawals for irrigation uses were considered to be of relatively poor accuracy. A review of the WRATS database indicated 44 water rights listing Qa's for irrigation use (or numbers of irrigated acres) and 119 claims listing Qa's for irrigation use (or numbers of irrigated acres). About 230 more claims list irrigation as a principal use, but do not list numbers of irrigated acres. For the purpose of this analysis, groundwater use for irrigation was assumed equal to the Qa's stated by water rights or the allowable irrigation applications calculated at Ecology's assumed rate of 2 af/yr per acre. All rights and claims listing Qa or irrigated acreage were counted. The accuracy of the irrigation water-use estimate is largely unknown because:

- the records in the WRATS database are largely dominated by claims;
- only 35 percent of the claims list number of acres irrigated;
- the number of claims for which irrigation water use has been perfected is unknown; and,
- the number of perfected groundwater rights for irrigation is also unknown.

Tables 4-9a and 4-9b presents a summary of estimated groundwater use in WRIA 17 using per hookup rates of 180 or 250 gpd/hookup. Total estimated groundwater use amounts to about 5,250 to 5,750 af/year depending on whether 180 or 250 gpd/hookup is assumed. Of this amount, about 2,984 af/yr is estimated from irrigation rights and claims. If estimated use from WRATS data is considered to be "lower quality", approximately 52 to 57 percent of the groundwater use in the WRIA is estimated from "lower quality" data. The remaining estimate of domestic and commercial use from large purveyors, public water systems, and single family domestic wells, is considered to be based on "higher quality" data. The largest groundwater withdrawals occur from the Chimacum, Ludlow and Quimper sub-basins.

Table 4-9a. Estimate of Groundwater Use Assuming 180 gpd per Residential Hookup

Sub-basin	Irrigation Water Rights/ Claims (af/yr)	Reported Use (af/yr)	Number of Hookups in WDOH Database (non-reporting systems)	Use from Public Water Systems in WDOH Database (non-reporting) (af/yr)	Single Domestic Wells	Single Domestic Well Use (af/yr)	Total Groundwater Use (af/yr)
Big Quilcene	120	0	60	12.0	589	118.8	251
Chimacum	1139	530	10	2.0	1034	208.6	1879
Dabob-Thorndkye	24	0	63	12.8	169	34.1	71
Indian-Marrowstone	184	0	9	1.7	361	72.9	258
Little Quilcene	108	0	38	7.7	601	121.3	237
Ludlow	949	278	113	22.9	488	98.4	1348
Miller	159	75	123	24.7	155	31.3	290
Quimper	216	109	566	114.3	611	123.3	562
Salmon-Snow	10	0	5	1.0	523	105.6	117
West Sequim	77	0	330	66.6	481	97.1	241
WRIA 17	2984	992	1316	266	5012	1011	5253

Table 4-9b. Estimate of Groundwater Use Assuming 250 gpd per Residential Hookup

Sub-Basin	Irrigation Water Rights/ Claims (af/yr)	Reported Use (af/yr)	Number of Hookups in WDOH Database (non-reporting systems)	Use from Public Water Systems in WDOH Database (non-reporting) (af/yr)	Single Domestic Wells	Single Domestic Well Use (af/yr)	Total Groundwater Use (af/yr)
Big Quilcene	120	0	60	16.7	589	165.1	302
Chimacum	1139	530	10	2.8	1034	289.8	1961
Dabob-Thorndkye	24	0	63	17.7	169	47.4	89
Indian-Marrowstone	184	0	9	2.4	361	101.2	287
Little Quilcene	108	0	38	10.6	601	168.4	287
Ludlow	949	278	113	31.7	488	136.7	1395
Miller*	159	75	123	34.3	155	43.4	312
Quimper	216	109	566	158.7	611	171.3	654
Salmon-Snow	10	0	5	1.4	523	146.6	158
West Sequim Bay*	77	0	330	92.5	481	134.8	304
WRIA 17	2984	992	1316	369	5012	1405	5749

Notes: Single domestic wells for the Miller and West Sequim Bay sub-basins were estimated based on well log databases rather than population estimates, and are of lower accuracy than other sub-basin estimates.
"Reported Use" represents public water systems that directly report groundwater withdrawals for domestic (or combined domestic/commercial) uses.
"Non-reporting" systems include those public water systems on file in the WDOH database from which direct reports of groundwater withdrawal were not available for this study.

Exhibit 11 shows the geographic distribution of groundwater withdrawals summed by square-mile section. The map was constructed based on an assumed use of 250 gpd/hookup. Unfortunately, population based estimates for single family domestic wells were unavailable on a section-by-section basis. In order to provide some representation of single family domestic wells, well counts were obtained from the Jefferson and Clallam County well databases for each section. Exhibit 7 differentiates the "data quality" of groundwater withdrawal estimates by the color of symbol plotted in each square-mile section. Reported groundwater withdrawals and withdrawals estimated from the WDOH public water system database were considered to be "higher quality data", and WRATS irrigation estimates and single family withdrawals based on well logs were considered to be "lower quality data". Groundwater withdrawal estimates per square-mile section are grouped into four categories based on percent of high quality data.

4.2.3.1 *Groundwater Allocation and Use: Data Limitations and Considerations*

Groundwater right applications and non-exempt water rights are well characterized for WRIA 17. Limitations on characterizing allocations in the WRIA are associated with exempt rights, claims, and categorizing groundwater rights by purpose of use. The factors preventing good estimates of exempt groundwater allocations and potential allocations associated with claims are intrinsic to the State's water right system. For exempt groundwater rights, reasonable estimates of numbers of wells and maximum associated allocations (at 5,000 gpd per well) can be derived. However, the discrepancy between the allocation and the actual use is so large that estimates based on these values are likely to be highly inaccurate. Estimating allocations through claims is equally difficult. Information is generally lacking as to whether these claims have been put to use, and many of the claims submitted listed irrigation as a principal use but did not report numbers of irrigated acres. The majority of claims were submitted 25 years ago, and the degree to which people use water for irrigation and stock may have changed significantly since then. In addition, the nature of the claims process may have promoted people to "hedge their bets" and submit claims for water that they planned to eventually apply to their acreage for irrigation. Adjudication, a potentially costly and time consuming process, would be required to distinguish perfected claims from non-perfected claims (which would be disqualified). A water right that

is not used over a continuous period of five years may also be disqualified by Ecology and lose its legal status.

The accuracy of the water rights breakdown by purpose of use is limited by the accuracy of Ecology's WRATS database in this area. The database contains a table that presents a specific allocation for each purpose associated with an individual water right. However, instances were noted where use data were either missing or entered incorrectly. The breakdowns of water rights by purpose of use presented in this report should be seen as approximate, indicating general patterns of use associated with allocations for the entire WRIA and for individual sub-basins.

The groundwater use estimate is comprised of about 55 percent agricultural withdrawals for irrigation. The data used to estimate irrigation water use is considered to be "lower quality" than the data used to estimate domestic and C and I use. Thus, the reliability of this portion of the water-use estimate could be improved. It was beyond the scope of this assessment to contact individual farmers in an attempt to estimate actual groundwater use. Further investigation, especially in cooperation with Washington State University (WSU) Extension, may improve groundwater use estimates for irrigation.

The estimation accuracy for single family domestic groundwater use is considered good in all sub-basins besides Miller and West Sequim Bay. In these two sub-basins, counts of well logs in county well databases were used to estimated single family sources, and are likely to be significantly underestimated. The well log databases are unlikely to include all active wells because some wells were installed before registration was required by Ecology (1972) and other wells were likely never registered or had records lost. Table 4-7 shows the degree to which counts of well logs would have underestimated single family domestic use in the remaining WRIA sub-basins. Finally, it should be noted that not all the groundwater withdrawals associated with the above estimates are fully consumptive. Septic systems are used in all areas of the WRIA to dispose of household wastewater, except for Port Townsend and Port Ludlow which use sewage treatment plants (Christensen 2000 personal communication). Previous studies have assumed that 87 percent of domestic water use is returned to the ground in the form of septic tank effluent (Solly et al. 1993). Based on that ratio, and assuming septic use for all hookups except for those supplied by Ludlow Water Company, estimated consumptive groundwater use for non-agricultural purposes may be in the range of 560 to 650 af/yr rather than the 2,270 to 2,770 af/yr shown on Tables 4-9a and 4-9b. Agricultural irrigation water may also be applied at rates exceeding the consumptive use of the crop. In such cases, a portion of the irrigation application is also returned to the groundwater flow system.

4.2.4 Surface Water Allocation and Use

Table 4-10a presents the consumptive surface water-right data for WRIA 17, and Exhibits 12 and 13 show the geographic distribution of Qi and Qa summed by square-mile section, respectively. The sum of consumptive use surface water rights is estimated to be 63.6 cfs. The annual allocation of WRIA 17 surface rights from the database totals 3,468 af/yr. The majority of allocation occurs in the Biq Quilcene and Little Quilcene Rivers because of the City's diversions. No annual quantities were listed for the City's rights on the Big Quilcene and Little Quilcene Rivers; however, their water use was obtained and entered on Exhibit 12 and 13. The City uses a total of 21,679 af/yr from the Big Quilcene River, and 2,295 af/yr from the Little Quilcene River. The next largest surface water use occurs in the West Sequim Bay sub-basin followed by the Ludlow sub-basin. Other than the Big and Little Quilcene River sub-basins, the majority of surface water use is for irrigation. Water right allocations for each sub-basin are described by quantity and by types of use in Chapters 8 through 17.

There are 287 surface water claims in WRIA 17 representing a potential instantaneous use of 45.5 cfs, and annual use of about 2,000 af/yr. Exhibits 14 and 15 show the geographic distribution of surface water

Table 4-10a. Summary of Surface Water Rights, in WRIA 17 Consumptive Use Only

Sub-basin	Count of Rights	Rights Sum of Qa-AF	Rights Sum of Qi-CFS	Rights Sum of Acres Irrigated	Count of Claims	Claims Sum of Qa-AF*	Claims Sum of Qi-CFS	Claims Sum of Acres Irrigated	Count of Applics	Applics Sum of Qi-CFS	Applics Sum of Acres Irrig
Big Quilcene	26	565.2	33.39	274	29	286	2.86	143			
Chimacum	20	580	2.925	285	42	702.56	6.598	350			
Dabob-Thorndkye	52	82.59	2.309	45	83	208.34	2.96	100	3	1.54	13.5
Indian-Marrowstone					1	8	0.08	4	1	0.02	5
Little Quilcene	38	445.47	11.95	218	19	170	1.7	85	1	0.01	
Ludlow	51	581.92	3.562	297.8	48	151.5	26.5	95	3	0.55	49
Miller	11	146	1.02	104.5	13	24	0.24	12	1	0.0001	
Quimper	1	0	0.02		9	180	1.8	90			
Salmon-Snow	24	258	1.635	129	21	192	2.02	101			
West Sequim Bay	57	809.14	6.8	485.32	22	70	0.7	35			
WRIA 17	280	3,468.32	63.611	1,838.62	287	1,992.4	45.458	1015	9	2.1201	67.5

*Values for claims as annual quantities (Qa) reflect irrigated acreage estimates alone. Many claims failed to report irrigated acreage, and associated Qa data could not be estimated. Domestic use, associated with most all claims, is not reflected in the Qa numbers.

Note: Tribal water rights are unquantified and are senior to all existing water rights.

claims by Qi and Qa, summed by square mile section. While this represents about 70 percent of the "officially allocated" surface water rights, the validity of these claims has not been determined. If adjudication were performed, a portion of these claims would likely not be perfected. One of the claims in the Ludlow sub-basin is for an instantaneous rate of over 20 cfs. It is unlikely Ludlow Creek could supply enough water to support a diversion that large and the claim is likely spurious.

Figure 4-5 provides a breakdown of WRIA 17 surface water rights by purpose of use. Not all of the water rights in the WRATS database are listed in the table of allocation by use. The largest allocation in the WRIA is for municipal use (87 percent), followed by irrigation (about 13 percent) and the remaining uses are less than 1 percent of the total.

There are nine applications for surface water rights in the WRIA with a combined Qi of 2.1 cfs. Qa is typically not reported for applications, but is negotiated at the time of permitting. Exhibit 16 shows the geographic distribution of Qi summed by square-mile section. The largest applications occur in the Dabob-Thorndyke sub-basin (for irrigation) and the Ludlow sub-basin (also for irrigation).

4.2.4.1 *Surface Water Use*

The primary use of surface water used in WRIA 17 is for municipal purposes by the City of Port Townsend and manufacturing use by the Port Townsend Paper Company. Their total consumptive use is estimated to be 87 percent of the surface water rights total estimated consumptive use in the WRIA. Water diversion and use data was obtained from the City (CH2MHill 1998) and is summarized in Table 4-10b. Water use data from other water users such as irrigators was not available and these water uses were estimated using water allocations.

Table 4-10b. Surface Water Use City of Port Townsend/Port Townsend Paper Company

	Annual Average Water Use	
Water Source	**cfs**	**Af/year**
Big Quilcene River	17.9	12,916
Little Quilcene River	4.1	2,963
Totals	22.0	15,879

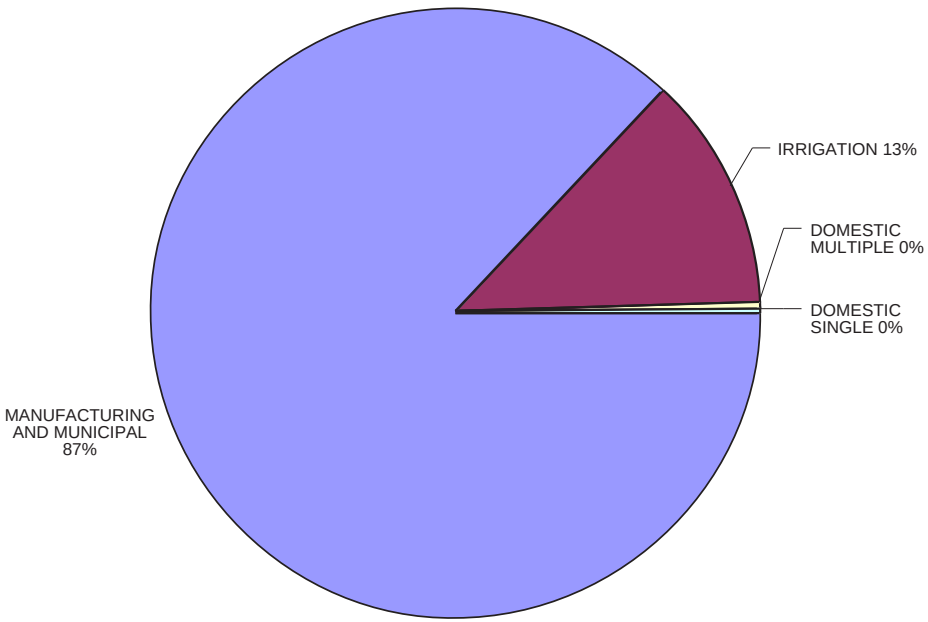
4.2.4.2 *Surface Water Allocation and Use: Data Limitations and Considerations*

Surface water rights are well characterized for WRIA 17. Limitations on characterizing allocations in the WRIA are associated with claims as discussed in the previous section on groundwater use data limitations. The City's water diversions from the Big and Little Quilcene Rivers are the predominate consumptive use of water, representing 87 percent of the volume of surface water rights on an annual basis. If claims are considered, the City's rights still represent about 81 percent of the total annual diversion quantity. For the entire WRIA, a large portion of surface water use is not known, and for sub-basins other than the Big Quilcene and Little Quilcene River, there is not sufficient information on actual water uses to accurately portray the amount of surface water that may be used.

4.3 PRELIMINARY WATER BUDGET

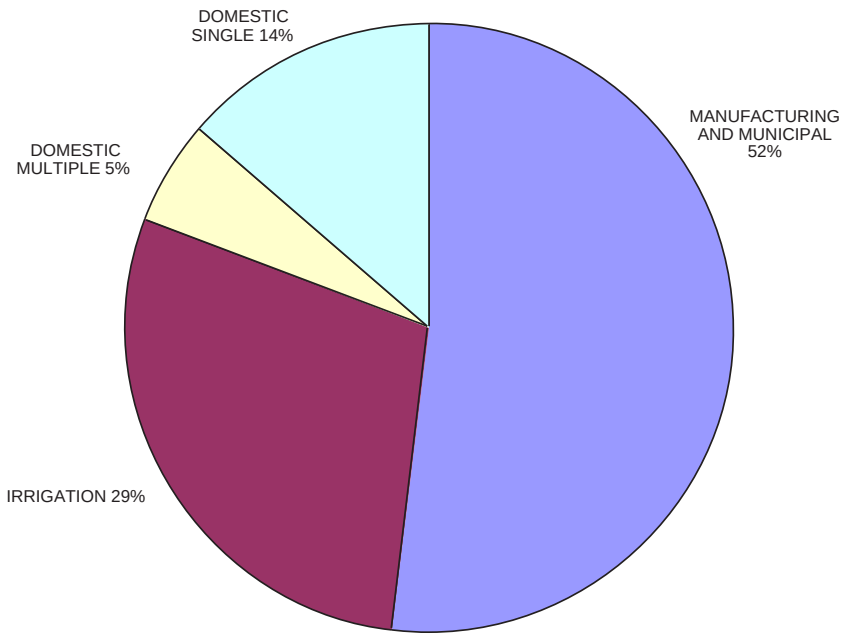
A water budget analysis is a useful tool to relate natural components of the hydrologic system to existing withdrawals and/or allocations. The water budget is a conceptual tool for understanding the pathways by

SURFACE WATER RIGHTS (QA) BY USE



Note: total allocation = 3468 af/yr, accounted by purpose = 3585 af/yr, additional non-consumptive rights 18130 af/yr

SURFACE WATER RIGHTS (QI) BY USE



Note: total allocation = 64 cfs, accounted by purpose = 77 cfs, additional non-consumptive rights = 98 cfs

Source: Ecology WRATs database

Figure 4-5
WRIA 17 Surface Water Rights and Use, Consumptive Use Only

which water enters, flows through, and leaves a watershed. It can provide a useful starting point for consideration of water quantity, water quality, and habitat issues. Water budgets, however, cannot be rigorously used to assess resource availability because they do not allow prediction of system response to additional withdrawals.

4.3.1 Preliminary Water Budget Components

A water budget is an assessment of the major components of a hydrologic system and includes the interactions between surface water and groundwater systems. This assessment can provide a general understanding of the magnitude of the recharge and selected discharge components. In general, however, it does not provide an accurate assessment of surface water/ground water interactions and quantities and should therefore not be relied on as the sole tool for water resource management.

A simplified water budget can be summarized as follows:

- Precipitation = Runoff + Groundwater Recharge + Evapotranspiration

There are a number of other components of a water budget that need to be addressed if a detailed review of surface and groundwater resources is desired. Those components include groundwater and surface water uses, groundwater discharge to saltwater, spring discharge (especially near the coast), change in groundwater storage, timing of groundwater discharge and others. The components of a simplified water budget are described in the following sections.

4.3.1.1 *Precipitation*

Precipitation includes rainfall, snowfall, and even condensation (which can be a factor in areas subject to lengthy periods of fog). As described in Chapter 2, the total quantity of precipitation that falls within WRIA 17 or sub-basin was estimated from available precipitation records. Precipitation (rainfall) varies dramatically from 15 to 20 inches a year in the north portions of the WRIA to more than 80 inches a year in the southwest portions of the WRIA. An evaluation of precipitation data results in an estimate of 778,000 af/yr of average annual rainfall. Precipitation either is evaporated or absorbed (and transpired) by plants, recharged to groundwater, or runs off land surfaces and flows to Puget Sound through storm drains, streams, or rivers.

4.3.1.2 *Runoff*

Runoff is the water that flows overland or in the shallow subsurface and quickly reaches surface water bodies such as streams, rivers, lakes, or the sea. In WRIA 17, runoff generally quickly ends up in Puget Sound or Hood Canal. An accurate estimate of total annual runoff in WRIA 17 is not available for most of the sub-basins. The Big Quilcene, Little Quilcene and Chimacum sub-basins have stream gages that are located close enough to the mouth of the sub-basin to allow an estimate of the annual runoff. Even so, the period of record for each of the gages near the mouth of those streams is not long enough to provide a good, long-term estimate of runoff.

4.3.1.3 *Groundwater Recharge*

This is the portion of precipitation that infiltrates past the root zone and enters the groundwater system. Groundwater is stored for a time within the WRIA; however, virtually all groundwater ultimately flows into a marine or freshwater body somewhere or is removed via pumping. Groundwater discharges to a surface water body may occur in the same sub-basin, or groundwater may flow into another sub-basin or

even to another WRIA. Depending on hydrogeological conditions, groundwater flow to surface water may occur within hours, days, years, or even centuries.

An estimated 141,000 af/yr of rainfall percolates beneath the root zone (recharges).Some of the water that recharges will resurface through springs and seeps forming the base flow for streams and rivers. Estimates of total base flow for streams and rivers in the WRIA have not been completed.

4.3.1.4 *Evapotranspiration*

Water vapor is continuously evaporated from the earth's land and water surfaces. Water present in soils is extracted by plants through transpiration and results in the release of water vapor into the atmosphere. The combined process is called evapotranspiration. Estimates of evapotranspiration were prepared for combinations of precipitation, soils and land cover, but were not compiled on a sub-basin basis. Our estimate of evapotranspiration varies from approximately 13 to 23 inches per year, for a range of 20 to 70 inches per year of precipitation. Figure 4-6 illustrates the evapotranspiration estimates for various annual precipitation volumes.

4.3.2 Simplified Water Budget

It is important to note that the simplified water budget described in this assessment does not fully capture all-important elements of the movement of water through WRIA 17 sub-basins. For example, some sub-basins include substantial importation of water from other sub-basins through pipelines or storage in reservoirs. In addition, groundwater flow does not always follow the same divides as surface water flow. Therefore, groundwater may flow into or out of a sub-basin or across sub-basin boundaries. Table 4-11 presents the available data for water budget component estimates for each sub-basin.

Table 4-11. Estimated Preliminary Water Budget by Sub-Basin

Sub-Basin Name	Drainage Area (A) (acres)	Average Precipitation (P) (inches/yr.)	Total Precip. Inflow (ac-ft/yr.)	Average ET (inches/yr.)	Average Recharge (inches)	Total Areal Recharge (ac-ft/yr.)	Estimated Surface Water Runoff (ac-ft/yr.)
Big Quilcene	51,509	52	222,776	20	2	10,279	Approx. 150,000
Little Quilcene	28,065	48	111,091	18	6	14,652	Approx. 40,000
Dabob-Thorndyke	33,116	39	108,455	17	14	39,743	N/A
Ludlow	25,537	30	63,417	17	10	21,237	N/A
Chimacum	23,681	27	53,677	16	6	18,712	Approx. 30,000
Salmon-Snow	27,736	36	82,052	17	4	9,461	N/A
West Sequim	24,136	28	56,720	16	3	6,478	N/A
Miller	16,656	25	34,839	15	6	8,115	N/A
Quimper	18,514	22	33,171	15	6	8,980	N/A
Indian-Marrowstone	6,491	22	11,900	15	6	3,002	N/A
Totals	**255,441**	**328**	**778,098**	**N/A**	**63**	**140,659**	**-**

Notes:

AET values derived from Figure 4-6 and Exhibit 2.

Precipitation values are based on the isohyetal map presented in Exhibit 2.

Areal recharge represents the total recharge to shallow and deep aquifers. A portion of the shallow aquifer recharge provides baseflow to streams.

Some of the groundwater that is extracted (as well as diverted surface water) is returned to the subsurface by irrigation and septic systems. Large quantities are processed through sewage treatment plants and

discharged to sea. Total sewage treatment plant discharge was not available for this Stage 1 study. The remaining recharge flows to Puget Sound and the Hood Canal where it emerges underwater through submarine springs. The total amount of flow via this path has not been determined.

A water use that has not been quantified is the optimum instream flows that may potentially be needed to sustain fisheries. Although the consumptive water use in WRIA 17 may be a small percentage of the overall flow in the rivers and streams when viewed on an annual basis, the water use may be a larger percentage of stream flow during the summer low flow period. In addition, optimum instream flows identified in previous studies are greater than median flows for most streams where gaging data is available (see Chapters 8 through 17).

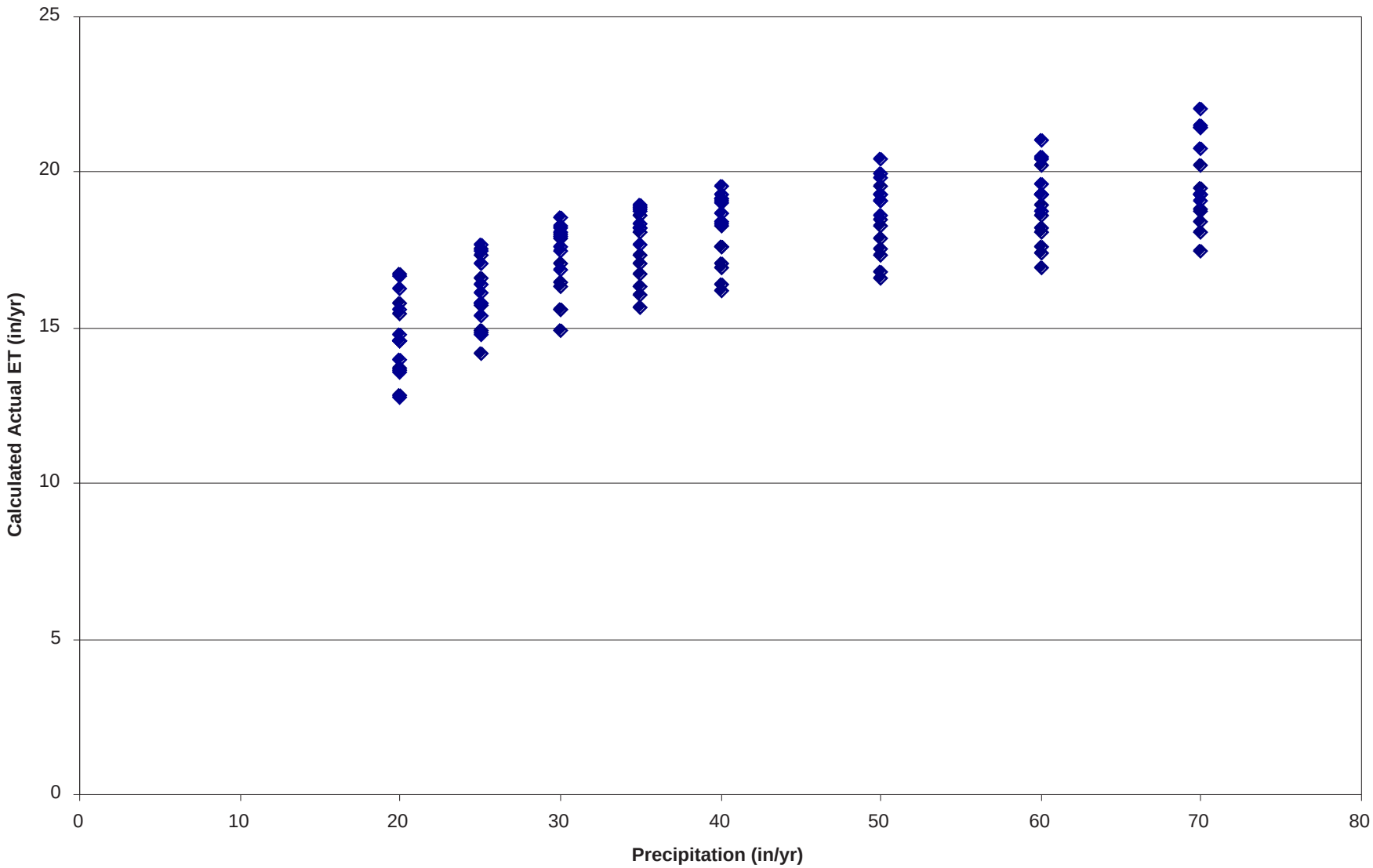
The water budget of an aquifer system is not a fixed condition. It will change seasonally and from year to year. All the components of the water balance can deviate dramatically over time from natural and/or human activities.

4.3.3 Comparing Groundwater Quantity with Use

Estimates of groundwater allocations and groundwater use have been developed in the sections above, and estimates of groundwater recharge have been developed in earlier sections of this report. Given this combination of information, it may be informative to perform a comparison between groundwater recharge and actual and potential use (i.e. allocation). Such a comparison appears similar to a water budget, in which all the inflows and outflows to the groundwater flow system are compared, and one can discern the most- and least- prominent components of the system. A preliminary water budget for the groundwater flow system in WRIA 17 would require estimates of groundwater recharge, groundwater discharge to streams, stream losses to groundwater, spring discharge, pumping withdrawals, change in storage and coastal discharge to marine water bodies. Some of these components may not be relevant for certain areas of the WRIA. On the sub-basin scale, a water budget would also require some estimate of groundwater flow across sub-basin lines, or “subflow”.

As shown in Table 4-12, groundwater recharge predicted for the entire WRIA is on the order of 140,000 af/yr. Groundwater allocations are estimated to be about 8,100 af/yr. Claims to groundwater allocations amount to over 3,200 af/yr, however many claims may not be perfected and actual allocations (should an adjudication be performed) may be lower. In a similar light, exempt water rights for single domestic wells in the WRIA could amount to as much as 28,000 af/yr; however, the likelihood that this quantity of water is actually used is extremely low. Groundwater use estimates, which take single domestic wells into account, predict actual groundwater use to be on the order of 5,750 af/yr.

These numbers suggest that actual groundwater use represents about 4 percent of recharge, and that legally allowable groundwater use (i.e. allocations) represents between 6 percent of recharge (based on non-exempt water rights) and as much as 28 percent of recharge (should all claims, exempt and non-exempt rights be perfected). While it is apparent that groundwater recharge far exceeds actual use, this conclusion should not be used to evaluate groundwater availability on a site-by-site basis. The proportion of groundwater recharge going towards maintaining baseflow in streams and offsetting saltwater intrusionalong the coast has not been estimated. While it may seem like ample recharge is available to support these other components of the groundwater flow system, such an evaluation must be made on a case-by-case basis. In addition, water budgets alone should not be used to determine groundwater availability.



Note: Analysis covers a wide range of soil moisture holding capacities (0.05-0.35 in/in), grass and forest vegetation, and till and outwash surficial geology.

Figure 4-6
Modeled Actual Evapotranspiration vs. Precipitation in WRIA 17 Lowland Areas

Table 4-12. Comparison of Water Rights and Claims by Sub-basin to Volume of Surface and Groundwater

Sub Basin Name	Est. Groundwater Recharge (ac-ft/yr.)	Groundwater		Total Rights and Claims (ac-ft/yr.)	Net Ground-water (ac-ft/yr.)	Est. Surface Water Runoff (ac-ft/yr.)	Surface Water		Total Rights and Claims (ac-ft/yr.)	Net Surface-water (ac-ft/yr.)	Pending Application		
		Rights (ac-ft/yr.)	Claims (ac-ft/yr.)				Rights (ac-ft/yr.)	Claims (ac-ft/yr.)			Ground-water (GPM)	Surface Water (cfs)	Total Appl. (GPM)
Big Quilcene	10,279	712	90	802	9,477	150,000	22,244	286	22,530	127,470	2,020	0	2,020
Little Quilcene	14,652	70	88	158	14,494	40,000	445	170	615	39,385	569	0	574
Dabob-Thorndyke	39,743	491	20	511	39,232	N/A	83	208	291	N/A	120	2	813
Ludlow	21,237	1,407	864	2,271	18,966	N/A	582	152	734	N/A	473	1	721
Chimacum	18,712	2,124	348	2,472	16,240	30,000	580	702	1,282	28,718	745	0	745
Salmon-Snow	9,461	19	10	29	9,432	N/A	258	192	450	N/A	0	0	0
West Sequim	6,478	368	60	428	6,050	N/A	809	70	879	N/A	0	0	0
Miller	8,115	1,045	116	1,161	6,954	N/A	146	24	170	N/A	1,740	0	1,740
Quimper	8,980	1,817	84	1,901	7,079	N/A	0	180	180	N/A	460	0	460
Indian-Marrowstone	3,002	42	164	206	2,796	N/A	0	8	8	N/A	0	0	9
Totals	140,659	8,095	1,844	9,939	130,720	220,000	25,147	1,992	27,139	195,573	6,127	2	7,082

Notes:

Water rights allocations based on Water Rights Information System (WRIS) data obtained from Jefferson County.

Surface water runoff is approximate.

Application quantity represent instantaneous withdrawal rates (Qi) expressed in gallons per minute (GPM) for ground water applications and cubic feet per second (cfs) for surface water applications.

The location of wells within the framework of the groundwater flow system must be considered to predict the effects of pumping on baseflow and saltwater intrusion. Knowledge of hydraulic continuity between aquifers and streams, and groundwater levels in coastal aquifers are needed for such an evaluation. In addition, acceptable levels of impacts to stream baseflow and coastal groundwater levels (and associated chloride concentrations) should be defined.

4.3.4 Comparing Surface Water Quantity to Use

Very little surface water data are available to enable a comparison of surface water quantity to use. Diversion of surface water for beneficial use in WRIA 17 is not extensive. The City of Port Townsend has two major divisions that combined may provide up to 39.56 cfs however, annual use is approximately 22 cfs. It is estimated the surface water use in streams other than the Big and Little Quilcene Rivers is 20 to 40 cfs. Total surface water rights and claims in the WRIA amount to 109 cfs and 5460 af per year. The annual use numbers for water rights applications is low because of the lack of information contained in the water rights database.

The sub-basins with some streamflow data are the Big Quilcene and Little Quilcene Rivers and Chimacum Creek. For the Big Quilcene River, the estimated diversions are approximately 12,900 af/yr by the City of Port Townsend. The total annual runoff is approximately 150,000 af/yr at the mouth of the river. That estimated volume of runoff does not include the City's diversion. The City diverts about 8 percent of the total flow in the Big Quilcene River on an annual basis. That ratio varies substantially depending on demands and streamflow present in the Big Quilcene River.

On the Little Quilcene River, the estimated runoff is 40,000 af/yr at its mouth. The City diverts about 3000 af/yr, or about 7 percent of the flow on an annual basis. That diversion ratio also varies substantially depending on demands and streamflow present in the Little Quilcene River.

On Chimacum Creek, the estimated runoff is approximately 30,000 af/yr. Surface water demands are not well characterized in this sub-basin. Based upon water rights records, 580 af/yr are allocated, which is approximately 2 percent of the total volume of runoff on an annual basis. However, the demands occur during the summer period when streamflows are low and are likely a much greater percentage of flow than indicated. Groundwater connectivity with Chimacum Creek and the effects of irrigation withdrawls, although not quantitatively known, may have an impact in surface water quantity.

4.4 HYDRAULIC CONTINUITY POTENTIAL

Hydraulic continuity refers to the interconnection between water bearing units, both groundwater and surface water. An aquifer is typically in hydraulic continuity with lakes, streams, rivers, and other surface-water bodies where saturation is continuous to the edge of these water bodies. Hydraulic continuity can occur where groundwater discharges to surface water, such as in spring-fed lakes and gaining streams; or where surface water discharges to groundwater, such as from riverbed seepage to an adjacent alluvial aquifer. Where hydraulic continuity exists, changing hydraulic conditions in a groundwater body will result in changes to connected surface-water bodies. For instance, pumping a well may result in reduced groundwater discharge to adjacent surface water or increased seepage from surface water. Similarly, lowering the water level in a lake or river may result in decreased seepage to groundwater or increased discharge from adjacent aquifers.

Determining or predicting cause-and-effect stream/aquifer relations can be simple or complex depending on the hydrogeologic conditions. In the case of groundwater withdrawals, potentially impacted surface

water bodies must first be identified. Because shallow aquifers are generally dominated by local groundwater flow systems, withdrawals from shallow wells are more likely to influence local surface-water bodies. Most simplistically, a shallow well in an alluvial aquifer will likely affect flow in the adjacent river or stream. Deeper aquifers are more typically part of regional flow systems. The effects of pumping from a deep confined aquifer could therefore be manifested on distant river reaches, discharge to coastal water bodies, or could be spread out diffusely over a large area to affect numerous surface-water bodies. The timing and magnitude of stream/aquifer interactions depends on many factors, including: the distance between the well and the surface-water body; the geometry and hydraulic properties of aquifers and aquitards between the well and the surface-water body; the frequency and magnitude of pumping; patterns of groundwater flow and recharge; and the hydraulic properties of riverbeds and lakebeds. Based on these factors, groundwater withdrawals may affect surface-water bodies almost instantaneously or may be delayed by months, years, or even decades. In general, the longest delays will be associated with deep wells that lie at large distances from surface water bodies. Similar delays can be expected in the effects of reduced or discontinued pumping.

4.4.1 Relative Hydraulic Continuity Assessment Methodology

For this assessment, a preliminary analysis of "relative hydraulic continuity potential" was conducted. The term "relative hydraulic continuity potential" (RHCP) was defined to differentiate between the types of aquifers to which a stream reach may exhibit hydraulic continuity. Specifically, RCHP differentiates between stream reaches potentially connected to principal aquifers, local perched aquifers, and geologic materials that typically do not comprise significant aquifers (e.g. bedrock or till). The measure is explicitly biased towards the hydraulic connection between surface-water bodies and principal aquifer systems, and less towards the hydraulic connection between surface-water bodies and localized, shallow aquifers perched atop lower permeability aquitards. Higher ratings of RHCP were assigned to stream segments potentially in continuity with principal aquifers because more of the overall groundwater withdrawal occurs from the principal aquifers. Localized, shallow aquifers may exhibit high continuity with streams, but are somewhat insulated from the regional groundwater flow system and were therefore assigned lower RCHP ratings. This bias towards emphasizing the effects of pumping from principal aquifers should be recognized up front, in tandem with the fact that current and future groundwater withdrawals emphasize development from principal aquifers.

It should also be clearly noted that RHCP is an estimated, relative parameter that is based primarily on assessment of surficial geology rather than detailed hydraulic or hydrogeologic analysis along streams. RCHP should be considered as a "screening factor" to focus attention on areas where withdrawals from principal aquifers could affect baseflow. Even where RCHP identifies a high potential for hydraulic continuity between stream reaches and geologic units likely to contain principal aquifers, the true degree of hydraulic connection can only be defined based on more detailed hydrogeologic evaluation. The RCHP index does not consider the role of other factors that can significantly affect hydraulic continuity between aquifers and streams such as the hydraulic conductance of the streambed, the presence of an unsaturated zone beneath the stream, or the presence of low permeability units within the principal groundwater flow system.

Surficial geology coverage was obtained in digital form from Jefferson and Clallam Counties and generalized for presentation by PGG. Exhibit 17 shows surficial geology in the WRIA generalized into four major categories: coarse unconsolidated sediments, fine unconsolidated sediments, till and bedrock. Our analysis, however, extended beyond this coverage and drew information from detailed geologic maps in USGS reports and published masters' theses (Birdseye 1976; Gayer 1976; Hanson 1977; Othberg and Palmer 1979). Despite the quality of the geologic information, data were largely lacking to incorporate other hydraulic and hydrologic elements into the analysis. The analysis is therefore considered to be *preliminary* because:

- hydraulic evaluation based on comparison of simultaneous groundwater-level, aquifer-pumping, and stream-baseflow trends could not be conducted due to lack of available data from monitoring;

- hydraulic evaluation based on analysis of pumping test data from wells located near streams is limited to one or two wells, and is generally inconclusive; and,

- evaluation of RHCP based on surficial geologic exposures within/adjacent to stream corridors does not take into account hydrogeologic factors such as variations in texture and permeability likely to occur within a given geologic unit and the presence or absence of subsurface saturation in the vicinity of the stream; and

- evaluation of *hydrogeologic* conditions in the vicinities of WRIA streams requires evaluation of well logs, construction of hydrogeologic cross-sections, and other detailed analyses; and is outside the scope of this Level I assessment.

Principal aquifer systems are herein defined as those systems that supply, or could supply, groundwater to most of the wells completed in a given area. For instance, many areas in the WRIA are capped by compact, low-permeability Vashon till (a.k.a. "hardpan"). Domestic wells are typically drilled through the till into deeper glacial or interglacial sediments to obtain sufficient water. In some cases the sediments underlying the till are highly variable in texture and finding water is a "hit-or-miss" exercise, while in other cases water-bearing units are more extensive and predictable. In either case, this assessment considers the sediments encountered beneath the surficial till to represent the principal aquifer. In some cases, current stream channels or former glacial outwash channels overlie till or bedrock, and may provide sufficient thickness and saturation to complete shallow domestic wells. With few exceptions, these shallow aquifers are not considered to be part of the principal groundwater flow system due to their local (channelized) extent and the till layer that separates them from deeper units. While hydraulic continuity may be high between these local aquifers and adjacent streams, RHCP is not considered high between the associated stream segments and principal aquifers.

The hydrogeology of glacial deposits in WRIA 17 can be complex, and many variations to the examples presented above may occur. For instance, a surficial outwash or alluvial channel can erode through the till aquitard into geologic units that potentially contain the principal aquifer system. Where this occurs, such as in coastal locations where streams cut through till down to sea-level elevation, high RHCP is assigned. It must be emphasized that hydrogeologic evaluation has not been performed to determine whether groundwater actually discharges to streams in these coastal locations. Rather, geologic conditions simply indicate the potential for a hydraulic connection between the stream and potential principal aquifer materials in this location. In another example, principal aquifer materials may be highly stratified with extensive aquitards separating deeper water-bearing units from shallower ones. The hydraulic continuity potential between streams and deeper water-bearing portions of the principal aquifer system is therefore less than for shallower portions of the principal aquifer system.

Special geologic or hydrogeologic conditions affecting RHCP occur in various locations throughout the WRIA. Some of these special conditions are identified in this analysis, while others require detailed site-specific investigation to discern. Due to these complexities, RCHP must be viewed as both a relative and generalized parameter. While a high RHCP rating represents higher potential for hydraulic continuity with principal aquifers than a medium rating, it does not necessarily represent a high absolute measure of hydraulic continuity. Given the likely occurrence of special conditions and the relative nature of the index, actual hydrogeologic investigation should be performed before using the index as a means to approve or deny groundwater development requests.

4.4.2 Overview of Relative Hydraulic Continuity in WRIA 17

RHCP is mapped for WRIA 17 streams on Exhibit 17. The following categories of relative hydraulic continuity potential are defined:

- *High RHCP* occurs where a stream segment or the higher permeability materials surrounding a stream segment have cut through the till aquitard and are incised into geologic units typically associated with the principal aquifer system. The word "potential" is emphasized here, because no hydrogeologic characterizations were performed to determine whether a direct hydraulic connection exists between the stream and the principal aquifer system or to evaluate the role of aquitards within the principal aquifer system.

- *Medium-High RHCP* is a special category reflecting some uncertainty as to the degree that a stream segment is in continuity with a local, perched system or the deeper principal aquifer system. This category is designated in areas where shallow sediments may comprise the principal aquifer system (i.e. the aquifer available to support most groundwater withdrawals) or where valleys cut into the principal aquifer system but low permeability swamp or bog materials underlie the stream.

- *Medium RHCP* occurs where permeable materials such as glacial outwash or alluvium may provide a shallow, localized aquifer along a stream, but are separated from principal aquifer systems by underlying till or bedrock. In this case, the stream is likely to exhibit relatively high hydraulic continuity with the adjacent shallow sediments but relatively low hydraulic continuity with principal aquifers. Because of the mixed potential for pumping impacts to baseflow, stream reaches exhibiting these characteristics receive a medium rating.

- *Low RHCP* occurs where stream segments directly overlay till aquitards or bedrock. The stream is therefore separated from the principal groundwater flow system by low permeability materials, and no significant shallow perched system occurs along the stream. Bedrock is assumed to be generally low permeability, and not included as a principal aquifer.

The distribution of RHCP is discussed on a sub-basin basis in Chapters 8 through 17 of this assessment. Much of WRIA 17 is covered with till or bedrock, and streams crossing these materials receive a low RHCP designation. Most of the stream reaches in the foothills of the Olympic Mountains and on the top, flat benches of various uplands fall into this category. Digital geologic coverage was missing from the southwestern portion of the WRIA occupied by National Forest lands. Because this area is comprised mostly of bedrock, a low RHCP was assigned. However, localized channels of alluvium or outwash may occur above the bedrock, and may warrant localized "medium" designations that are not shown on Exhibit 17. Few wells are expected to occur in the areas with missing geology GIS coverage.

Stream segments situated in outwash channels or alluvial valleys receive a medium RHCP designation. These designations are common in the Salmon-Snow, Little Quilcene and Big Quilcene sub-basins. Along the head of Quilcene Bay, where local outwash and/or alluvial sediments may be sufficiently thick to support many domestic wells, a medium-high RHCP is assigned to the stream segments crossing these sediments. This area represents an exception in that thickness' of alluvial/outwash material may be sufficiently thick to actually comprise the local principal aquifer. Medium-high RHCP's are also assigned to the valleys of Chimacum Creek, which cut into principal aquifer materials but include a surficial layer of low-permeability peat or marsh materials. High RHCP's are assigned to portions of Tarboo Creek, Thorndyke Creek, Shine Creek, Ludlow Creek and other unnamed creeks that cut directly into principal aquifer materials such as Vashon advance outwash and pre-Vashon glacial and interglacial sediments.

It is important to note that Exhibit 17 identifies stream segments likely to exhibit low, medium, medium-high and high measures of RHCP. The map can be used to infer reaches of streams potentially affected by pumping, but it does not specify where pumping must occur to effect baseflow in these stream reaches. It is not necessary for a well to be near to a high RHCP reach to effect baseflow in that reach. The hydraulic connection between an aquifer and a stream may be such that water flowing through distant regions of an aquifer supports baseflow observed farther downstream in the sub-basin. In this case, if a distant well withdraws water from an aquifer providing baseflow to a stream, baseflow will likely be reduced by some portion of this pumping withdrawal. Thus, an understanding of the sub-surface framework of aquifers and how they connect to streams and marine bodies is necessary to predict the degree to which pumping from a distant well is likely to impact baseflow along a high RHCP stretch of stream. The acceptable amount of baseflow reduction will depend on habitat, recreation, aesthetic, and other values for the stream. When warranted, hydrogeologic evaluation of impacts to baseflow (as a percentage of total pumping) can be used to assist in design of mitigation for groundwater withdrawals.

4.5 EFFECTS OF LAND USE VARIATION ON WATER QUANTITY

4.5.1 Potential Land Use Effects on Groundwater Quantity

Changes in land use may affect the availability of groundwater in WRIA 17 because groundwater is recharged via processes that occur at the land surface. Significant changes to land use could alter the timing of recharge, the magnitude of recharge, and/or its spatial distribution. For WRIA 17, four types of land-use alteration are identified that could potentially affect groundwater recharge, and thus water quantity. The four land-use alterations to be discussed relative to groundwater quantity are:

- Impervious surfaces associated with residential development;
- Changes in vegetative cover associated with residential development or agriculture;
- Water management associated with residential development; and
- Changes associated with logging.

Actual data documenting the relationships between land-use change and groundwater availability in WRIA 17 are unavailable. Estimates regarding changes in land-use areas over time were not available at the time of this study, and direct hydrogeologic data useful for comparison (e.g. trends in groundwater levels and/or stream baseflows) were also unavailable. The following text is based on general hydrogeologic understanding, the results of recharge modeling, and a literature review regarding the impacts of impervious surfaces and variations in land cover.

4.5.1.1 *Impervious Surfaces*

Impervious surfaces typically associated with residential and commercial development include rooftops, driveways, roads, and parking lots. Impervious surfaces can limited groundwater recharge by preventing local infiltration of rainfall and enhancing runoff to streams. Recent research distinguishes between *total* impervious area (TIA) and *effective* impervious area (EIA). Whereas total impervious area measures the percentage of land covered with impervious surfaces, effective impervious area measures only the impervious surfaces that provide a relatively rapid route for precipitation to run off to streams. When impervious areas are highly connected, EIA can comprise a significant portion of TIA. However, disconnecting impervious areas can significantly reduce the ratio between EIA and TIA (Scheuler 1995). This section presents a summary of published information regarding the relationship between groundwater recharge and impervious areas over the range of TIA typically observed within WRIA 17. Studies are unavailable to relate TIA to EIA in the WRIA, although ratios are likely to be relatively high in urban and heavy suburban areas.

Many studies confirm that increases in impervious area result in increases in stream runoff. Much of the available literature indicate that streams are impacted by increasing runoff intensity at TIA values ranging from 10 to 15 percent (Schueler 1994), and recent research indicates that altered flow regimes have impaired stream habitat at TIA values ranging from 5 to 10 percent (May et al. 1997). However, the relationship between TIA and groundwater recharge is not well established. The literature does not address this relationship directly; however, relationships between impervious areas and stream baseflows can be used to illustrate the connection. While it is generally accepted that above a certain TIA, both groundwater recharge and baseflow will be noticeably reduced, this threshold has not been well defined. Many of the studies relating impervious surfaces to stream functions do not directly address recharge or baseflow trends. Of the studies that do, the ultimate conclusions are mixed. Scheuler (1994) writes:

> *"Because infiltration is reduced in impervious areas, one would expect groundwater recharge to be proportionally reduced. This, in turn, should translate into lower dry weather stream flows. Actual data, however, demonstrate that this effect is rare. Indeed, Evett et al. (1994) could not find any statistical difference in low stream flow between urban and rural watershed after analyzing 16 North Carolina watersheds. Simmons and Reynolds (1982) did note that dry weather flows dropped 20 to 85 percent after development in several rural watersheds on Long Island, New York."*

A study by Klein (1979) compared 27 small watersheds in the Piedmont province of Maryland, with similar geology, physiography, but varying degrees of urbanization. The author concluded that baseflow is inversely related to percent impervious area; however, data were scant for watersheds with TIA's below 20 percent. This study illustrates one of the problems with defining the effects of impervious area on baseflow: many available studies tend to focus on moderately to highly developed areas (TIA's greater than 20 to 30 percent) and do not allow assessment of baseflow impacts at typical rural residential densities. Development at one dwelling per acre is associated with TIA's below 10 percent (Scheuler 1994) whereas development at 3 to 7 units per acre can result in TIA's ranging from 27 to 57 percent and EIA's ranging from 13 to 47 percent depending on the connectedness of impervious surfaces (Beyerlein, 1996). In some cases, studies which focus on urban areas may show little change in baseflow due to infiltration of exported water for irrigation of gardens and lawns (Schueler 1995).

Several communities within the WRIA are developed at densities above one unit per acre, including Port Townsend and Port Ludlow. Both of these communities discharge stormwater to marine bodies, and are likely to cause local reductions in groundwater recharge. Projected growth specifies increased population densities in these areas, rural village centers such as Quilcene, and possibly a future UGA (urban growth area) designation in the Tri-Areas. Without proper consideration of soil infiltration properties and stormwater management practices, recharge reductions may occur in these areas.

In other areas of the WRIA where development densities remain below 10 percent, the effects of increasing impervious area on recharge and baseflows cannot be estimated based on currently available information. In some instances, low densities of poorly connected impervious surfaces can actually increase groundwater recharge. The factors that determine the effects of impervious surfaces include the percent impervious cover, the routing of runoff from impervious cover, and the runoff or infiltration properties of the soils that surround impervious areas. Under natural conditions, most of the precipitation incident on the land surface enters the root zone, and is either taken up by plants or becomes groundwater recharge. Runoff from impervious surfaces is concentrated where it exits the paved surface and flows overland. Runoff is concentrated along the edges of driveways, along the footprints of buildings, or at the outflows of downspouts. If the runoff is not collected by a storm water system, it has the opportunity to infiltrate into the ground in a much more concentrated fashion than incident precipitation. In this case, the ratio of concentrated infiltration to plant uptake is much higher than under natural conditions, and less

of the water infiltrated will be lost to plants. Above a certain level of impervious surface, however, soils cannot accommodate the increased runoff from the impervious areas and storm runoff increases. Depending on the extent of impervious surface and the management of the storm water, regional runoff can increase and regional recharge can be reduced.

The cutoff point at which recharge is reduced also depends on the soil's innate ability to infiltrate water and the slopes (or drainage patterns) of the land. In outwash areas where soils are highly permeable, runoff from impervious surfaces is likely to immediately infiltrate into the soil and cause an increase in recharge surrounding paved surfaces. In till covered areas, slopes and drainage patterns control the fate of excess runoff generated by impervious surfaces. For flat till-covered areas, such as many of the upland areas in WRIA 17, runoff from paved areas may tend to pond above the till and slowly infiltrate through the till over time. In areas of gently undulating topography, runoff above till may be naturally routed to small depressions and swales, where it will also infiltrate over time. As note previously, infiltration through till is limited by the till permeability. Above a certain rate of application, recharge through till ceases to increase and rejected recharge (or runoff) is generated. Results of recharge modeling suggest that recharge through till shows little increase with increased soil infiltration in areas where rainfall exceeds 30 in/yr. However, this number is highly dependent on the assumed permeability of the till, which may vary over a relatively large range. Nevertheless, it should be recognized that, depending on pre-existing rainfall, some till-covered areas have additional capacity to further absorb recharge concentrated along the edges of impervious surface while others do not.

Over the entire spectrum of residential densities, the management of runoff generated from impervious surfaces will affect whether recharge is likely to increase or decrease, as well as the geographic distribution of recharge. Areas that employ storm water collection systems, and ultimately discharge storm water to marine bodies, will reduce groundwater recharge. In other locations, storm water may be locally collected in ditches along roads and discharged into natural depressions or retention basins. In this case, runoff from impervious areas is being concentrated into a relatively small area for infiltration, and recharge may increase. If runoff is routed far away from its source, however, this type of management can significantly alter the timing and distribution of recharge. Under natural conditions, recharge occurring on till-covered uplands slowly infiltrates through the till and recharges underlying principal aquifers at a relatively constant rate. If storm water is routed off the uplands into valleys, both the timing and location of the recharge is altered. Recharge becomes more seasonal and may occur closer to discharge bodies (i.e. streams), to be lost from the groundwater flow system more quickly.

4.5.1.2 *Changes in Vegetative Cover*

Different types of vegetation have differing water requirements and rooting depths, and thus take-up more or less water from the root zone. Since recharge is generally equal to precipitation minus runoff and plant uptake (evapotranspiration), altering vegetative cover can alter recharge. Residential development often results in modifying plant cover from forest to lawns and pastures. Estimation of recharge for both forest and grass cover, performed with the recharge model for the conditions considered in WRIA 17, showed little difference between recharge under grass and coniferous forests. On an annual basis the seasonality of recharge is predicted to vary, but the total amount shows little difference. The recharge model, however, took a simplified approach and did not distinguish among the runoff characteristics between forests, pastures and lawns. Recent research in applying runoff models (EPA "HSPF" model) to other till-covered regions of the Puget Sound lowland suggests definite differences in the runoff characteristics of forests and lawns (Dinicola 1990 and Beyerlein 1999) and implied differences between the runoff characteristics of forests and pastures (Beyerlein 2000 personal communication). While the models were generally applied to more developed areas in the region, the conclusions are likely applicable to portions of WRIA 17. The conclusions suggest that changes in vegetative cover, from forests to pasture and ultimately to lawns, result in an increase in runoff and a commensurate decrease in groundwater recharge.

In the Puget Lowland, storm runoff generally follows a subsurface flow regime, where runoff moves predominantly *through*, not over, the soil (Booth 1991). Shallow water tables, perched above till, rise with precipitation events to create more subsurface flow and ultimately saturate areas of the drainage basin. Overland flow occurs when rain falls on saturated areas of the basin, which increase in size with greater magnitude and duration storm events. The HSPF model estimates both components of total runoff: surface runoff and shallow interflow. Differing runoff characteristics between land covers are controlled by modeling parameters related to soil permeability, soil storage, surface roughness, and vegetative characteristics related to the depth of the root zone and canopy interception storage. During HSPF calibration to runoff from forests and lawns, these characteristics have been adjusted to match observed runoff behavior for various watersheds. Parameters for pasture have been estimated within the continuum defined by forest and grass (Beyerlein 2000 personal communication). A significant portion of the change in runoff characteristics between forests and suburban lawns is believed to arise from disturbance of native soils associated with development (Scheuler 1995). Development may involve grading of a site, removal of topsoil, erosion during construction, compaction by heavy equipment, and filling of depressions. HSPF model results using parameters developed for till-covered regions of the Puget Lowland and an annual precipitation rate of 40.7 in/yr indicate that total annual runoff from lawns is almost 9 inches higher than runoff from forest (Beyerlein 1999). This difference in total runoff is predominantly expressed as shallow interflow, and is predicted to correspond to a 4 in/yr reduction in groundwater recharge. Using parameters estimated for pasture, a predicted 4 in/yr increase in total runoff (again mostly interflow) corresponds to a 3 in/yr reduction in groundwater recharge (ibid).

The runoff and recharge relationships estimated using HSPF modeling are significant in that they suggest that development (conversion of forests to pastures and lawns) will increase total runoff and reduce recharge. Given the differences in development densities between the areas to which the model was applied (western King and Snohomish counties) and WRIA 17, the actual numbers may differ. The calibrated HSPF parameters for runoff characteristics of lawns may also partly reflect the runoff characteristics of the associated pattern of impervious surfaces, which may differ between these calibrated areas and WRIA 17. Despite possible variations in the numbers, the implications are compelling. Changes in vegetative cover associated with development, especially when they include soil compaction, are expected to result in some reduction in groundwater recharge. The HSPF analysis is largely focused on till covered soils, and relationships may differ in areas covered with high permeability (e.g. outwash) soils) where fewer factors limit infiltration of rainfall.

Alterations to groundwater recharge resulting from agricultural practices depend on the crops grown and the irrigation regime applied. Not withstanding the direct effects groundwater extracted for irrigation, irrigation applications and cropping patterns can affect the timing and magnitude of recharge. Depending on the rate of irrigation applications, crop uptake can utilize more of the natural precipitation and soil moisture available for recharge - thus decreasing groundwater recharge. However, if irrigation water is applied in excess of crop requirements, additional recharge can reach the groundwater flow system during the growing season. If the recharge water is acquired from surface water sources, groundwater recharge can increase locally from over-application of irrigation. In addition, if fields are left fallow during the rainy season, recharge can increase during this period. Although evaporation occurs from moisture stored in bare soil, evaporative loss is generally lower than the rate of evapotranspiration occurring when vegetation is present. Thus, more water is available to recharge underlying aquifers.

4.5.1.3 *Water Management Associated with Residential Development*

Water management practices associated with residential development can also affect water quantity. Besides the obvious issue of groundwater pumping associated with domestic wells, wastewater management practices can affect groundwater recharge and the balance between consumptive and non-consumptive use. In areas where wastewater is piped to sewage treatment plants and ultimately

discharged to marine water, groundwater pumped for residential use is entirely lost to the groundwater flow system. The full amount of domestic pumpage becomes consumptive since nothing is returned to the groundwater flow system through septic discharge. In areas where housing densities are low enough to permit the use of septic systems, water returned to the shallow groundwater flow system has been estimated at 87 percent of the pumping withdrawal.

A special circumstance regarding recharge of septic effluent that warrants mentioning for the Quimper and Chimacum sub-basins is the fact that prior to 1997, some areas with septic systems were supplied by surface water purchased from the City of Port Townsend. The septic effluent from residents receiving surface water from the Big or Little Quilcene Rivers is an additional source of recharge to the groundwater flow system, exported from outside the sub-basin. Changes to this arrangement can change the balance of pumping and recharge in an area. In the past, the Tri-Area was supplied mostly with surface water from the City of Port Townsend's system. With the recent installation of a new well at the Sparling Wellfield, the water used in the Tri-Area has shifted to a local groundwater source. The new well was complete approximately a year after the Tri-Area has switched to groundwater. Local pumping is required to meet area water usage (City). Although this does not cause the amount of recharge from septic systems to change, it means that local pumping may need to increase to meet the full demand with groundwater.

4.5.1.4 *Logging*

The impacts of logging on surface water runoff have been well documented. In many areas, particularly those with steep slopes, logging tends to cause heightened, more "flashy" runoff responses to rainfall events, increased sediment load in streams, and sometimes local landslides. The impacts of logging on groundwater recharge are not as well studied, and will tend to vary depending on the area logged. In this discussion, we are referring to large-scale logging as opposed to thinning of the forest. Immediately after logging, areas are largely stripped of vegetation and soils may be compacted due to road building and operation of heavy machinery. Specific groundwater effects depend in large part on forest practices and land cover characteristics. An initial change in recharge is expected immediately following logging, and the long-term effects will depend on the type of recovery the forest experiences.

Impacts to recharge for a recently logged area will depend on soil types, the presence or absence of shallow till, and topographic relief. In relatively flat areas or where soil types are highly permeable (e.g. derived from outwash), removal of vegetation is likely to increase recharge. This is because evapotranspiration from bare soil is less than evaporation from trees (including from water intercepted by tree foliage), and more water is available to flow downward to the uppermost aquifer. If relatively flat areas are covered by glacial till and precipitation is already high enough to exceed the till's capacity to transmit water, recharge will not increase significantly but will also not decrease due to vegetative clearing. In this case, the increase in runoff typically observed is not inconsistent with the increase in recharge, as both are a result of the decrease in evapotranspiration. However, in moderately or steeply sloping areas, soil compaction, loss of soil and removal of forest floor organic debris could increase runoff sufficiently to reduce recharge.

As plants repopulate a logged area, recharge will return back towards original conditions. Differences in water requirements between the early stages of forest recovery and the late stages may cause differences in recharge as the forest becomes re-established. If loss of topsoil has occurred, differences in the moisture retention capacity of the underlying subsoil could also change groundwater recharge. The particular direction of that change will depend on the specifics of the soil profile. In general, these factors suggest that more research may be needed on the effects of logging on groundwater recharge.

4.5.2 EFFECTS OF LAND USE ON SURFACE WATER QUANTITY

Changes in land use or cover can also have a significant effect on the rate and timing of surface water flow in rivers and streams. The types of land cover or land use changes experienced in WRIA17 include conversion of either forest or agricultural land to urban land uses (impervious surfaces); logging of forested lands and replanting with seedlings; and logging of forested lands and conversion to grass or agricultural uses. The effects of those changes are well described in the preceding section on groundwater, which is also relevant to surface water effects. The effect of each change is relative to the amount of land it disturbs, its location in the basin, the soils that underlie the area and the rainfall regime. A description of the potential effects of each of those changes on surface water quantity is listed in the following paragraphs.

Hydrologic models can be used to estimate the changes in streamflow resulting in land use changes. One model that is used throughout the Puget Sound region is the HSPF (Hydrologic Simulation Program – Fortran) model that is distributed by the Environmental Protection Agency. Such an effort was not undertaken for this study because of the cost and timeframe to perform this modeling exercise.

4.5.2.1 *Urban Land Use*

Urban land uses have a high percentage of impervious area (typically 10 to 25 percent or more). Rain falling on urban areas tends to run off quickly to streams, causing large increases in peak flows in streams during storm events. Because of the change in land use, less infiltration occurs during rainstorms, reducing between-storm flows and base flows that occur during the summer time.

4.5.2.2 *Logging*

Logged areas typically produce a greater volume of runoff because of a reduction in evapo-transpiration and interception from tree cover. In higher elevation areas, logging can increase the rate of snowmelt because increased exposure increases the heat transfer between solar radiation, warm rain and wind to the snowpack. If large areas are disturbed through road construction, additional impacts could result from increased runoff from compacted, mostly impervious area and an increase in the efficiency in transmitting water through the drainage network (i.e., through culverts and ditches). The effects on streamflow are typically an increase in peak flows during storm events. The effects of logging are felt for a number of years until new growth is sufficient to intercept and transpire moisture, reducing the amount of rainfall that is available for runoff.

4.5.2.3 *Conversion of Forested Lands to Agricultural and Residential Use*

This change is common for developing areas found in WRIA 17. Outside of urbanized areas, larger lots are common where residents clear an area for their house, septic tank and drainfield, and lawn. Some residents will keep a small number of livestock, requiring a cleared area. The effects of the conversion are an increase in surface water runoff during rainstorms and a decrease in infiltration because of the disturbed soils and compaction. The decrease in infiltration may often lead to a decrease in base flows in streams.

4.6 SUMMARY OF PROJECTED IMPACTS OF GROWTH ON WATER DEMAND

This section provides a WRIA wide summary of projected impacts of growth on water demand. Projected impacts specific to each sub-basin are described in Chapters 8 through 17.

Data available to characterize or predict future changes in growth are presented in Table 1-2 of Chapter 1. The lack of specific information regarding anticipated future land-use changes associated with this growth

make it difficult to predict related potential impacts to groundwater and surface-water quantities. However, general discussion of the relationships between these particular land uses, streamflow and groundwater recharge is included in Section 4.5.

Population growth is projected to increase 55 percent between 1996 and 2016, from approximately 25,000 to 38,000. On a WRIA-wide basis, population growth is estimated to increase water use approximately 33 percent over existing conditions. Predicted increases in water demand for each sub-basin based on existing population data is shown in Table 4-13. As shown in Table 4-13, this has potential to result in an approximate 1 to 2 percent increase in recharge used, which could increase the total amount of recharge used from approximately 4 percent under current conditions, to 6 percent in 2016.

4.7 CONSERVATION OPTIONS

Water resources to support future growth in WRIA 17 will be partially dependent on recognizing the value of water resources and the implementation of effective conservation plans. Conservation is a central element of State law, and is directed at both suppliers and consumers of water, and local Comprehensive Water Plans must incorporate conservation elements. With the exception of the City of Port Townsend water system, water withdrawals in WRIA 17 are typically geographically dispersed and individually small. For this reason, water conservation options for WRIA 17 would be expected to focus primarily on non-structural measures that improve water use efficiencies. These non-structural options may not require extensive capital investment but implementation may make a significant contribution to water conservation and efficiency. A brief description of conservation options for WRIA 17 follows.

4.7.1 Tiered Water Rate Structures

The structure of water rates can be an effective means of encouraging efficient water use and can promote an increased economic awareness of water use. Traditionally, water rates have reflected only a “fixed” charge or a “water rate” charge. Developing a rate structure that charges a higher rate for each incremental amount of water use can encourage water conservation. An option is to have an increasing charge for water used in periods of low streamflow, typically the late summertime. This alternative is applicable to areas served by public water supply systems.

4.7.2 Modification of Landscape Irrigation Practices

Reductions in outdoor residential water use is possible with landscape irrigation modifications. Approximately 30 percent of domestic water use is for lawns and gardens. Typically, between 20 and 30 percent of water applied to landscaping either evaporates or runs-off. More efficient irrigation practices, use of more drought tolerant species, better turf preparation, and use of landscape design that reduce high water consumption turf areas are all strategies that can be employed to lower water demand.

4.7.3 Water Conservation in Water Supply Systems and Individual Homes

This water conservation option includes reducing water loss and water use through leak detection programs in water supply systems and installing low water use fixtures in existing houses. Public water supply systems can have an audit of water use performed and determine how efficient their system is in delivering water. Standards for water loss can be established to guide water purveyors in their leak detection and prevention programs. Homes and businesses can also be furnished with low flow fixtures and appliances. A new water efficient home, which incorporates low flow fixtures and appliances, can reduce indoor water consumption by as much as 35 percent over a non-conserving home. Similar water saving devices can be installed in businesses. New houses are required to have low flow fixtures per State law so a program providing incentives for retrofitting existing houses would be needed.

Table 4-13. Summary of Population Projection and Distribution, and Potential Impact on Water Demand

WRIA 17 Sub-basin	Year 1996 Pop.	Year 2016 Pop.	Net Pop. Increase	Percent Pop. Increase	Est. Water Use Increase (af/yr)	Current Ground-water Use (af/yr)	Est. Percent GWU Increase (percent)	Estimated Recharge (af/yr)	Current Recharge Used (percent)	Increase in Recharge Used (percent)	Consumptive Increase in GW Use (af/yr)
Big Quilcene	1,299	1,943	644	50%	82	322	25%	10,279	3.1%	0.8%	11
Chimacum	5,675	7,284	1,573	28%	200	1,803	11%	18,712	9.6%	1.1%	26
Dabob-Thorndyke	411	596	185	45%	24	96	25%	39,743	0.24%	0.06%	3
Indian-Marrowstone	839	1,015	176	21%	22	287	8%	3,002	9.5%	0.7%	3
Little Quilcene	1,308	1,797	483	37%	62	287	21%	14,652	2.0%	0.4%	8
Ludlow	2,882	6,371	3,489	121%	444	702	63%	21,237	3.3%	2.1%	58
Miller	N/A	N/A	N/A	N/A	N/A	595	N/A	N/A	N/A	N/A	N/A
Quimper (Mixed GW and SW Analysis)	11,293	17,952	6,659	59%	848	670	n/a	8,980	7.5%	n/a	N/A
Quimper (GW only)	11,293	17,952	1,149	10%	146	670	22%	8,980	7.5%	1.6%	19
Salmon-Snow	1,085	1,470	385	35%	49	158	31%	9,461	1.7%	0.5%	6
West Sequim	N/A	N/A	N/A	N/A	N/A	307	N/A	N/A	N/A	N/A	N/A
Totals	**24,792**	**38,392**	**13,600**	**55%**	**1,732**	**5,227**	**33%**	**126,066**	**4.1%**	**1.4%**	

N/A = Not Available

Assumptions: Water use per hookup 250 gpd
Water use per capita 114 gpd
Water use per capita 0.127385 af/yr
Water use returned by septics 87%

4.7.4 Educational Programs

An important component of any water management program is providing information to water users about efficient water use and water management services available through the water supply entity or other organizations. Examples of educational programs include irrigation system improvement programs, on-farm irrigation scheduling programs, agricultural evapotranspiration programs, and technical and financial assistance programs. Many Federal and State Agencies provide this information through their technical and/or financial assistance programs. Some of the agencies providing this information are Natural Resources Conservation Service (NRCS), Washington State University (WSU), Cooperative Extension Service, and local Conservation District offices. The same type of programs can be extended to residential water users to provide real-time information on landscape water needs.

Examples of education/information/demonstration/technical assistance programs currently available to irrigators are listed below. These programs could be enhanced and extended through programs available from NRCS Environmental Quality Incentives Program (EQIP), the Washington Centennial Clean Water Program, Washington State Department of Ecology (Ecology), and other cost-sharing and granting programs:

- Best management practices for soil and water conservation. Irrigation Management Practices to Protect Ground Water and Surface Water Quality, State of Washington, WSU Extension Publications EM 4885, provides detailed information (WSU 1995).

- Irrigation method efficiencies. The State of Washington Irrigation Guide, a joint publication of the NRCS and WSU Cooperative Extension available in each NRCS and WSU Cooperative Extension office, provides considerable detail (USDA year?).

- Conservation oversight and funding. The two conservation districts in the WRIA have staff to assist farmers, irrigation districts and watershed groups with their on-farm conservation activities. The districts develop conservation demonstration projects, provide planning assistance, cost-share on-farm conservation measures, and provide oversight to all conservation activities occurring within their district.

4.7.5 Water Re-Use

Water re-use is defined by the state as “use of reclaimed water, in compliance with DOH and Ecology regulations, for direct beneficial use”. Reclaimed water is effluent from wastewater treatment systems that is adequately treated for reuse. The use of reclaimed water is becoming more accepted in the state and region as water resource managers and the public are made aware of the advantages. Water reuse is a potential conservation option for the public and private wastewater treatment facilities in WRIA 17.

4.7.6 Increased Storage, Either Through Surface Storage or Aquifer Storage

Increased storage can be accomplished by either constructing reservoirs to store water above the ground surface or to implement an Aquifer Storage and Recovery (ASR) program. The idea in either case is to divert flows during wet periods when streamflows are high and instream flows are met and store water for use when streamflows are very low. Storage can be provided either off-stream where water is diverted from the stream, stored in a reservoir and then supplied directly to a water supply system or in-stream. An instream reservoir captures high flows and releases those flows during the low flow period to be diverted by downstream water users or used to supplement instream flows. The applicability of this

option is limited to water users with surface water rights. The option is also limited by land availability, geology and environmental impacts. The City of Port Townsend has already implemented this as they have built and operate Lords Lake and City Lake. The City uses those lakes as storage reservoirs to reduce diversions during low flow periods. The potential exists for expansion of Lords Lake to provide additional storage.

4.7.7 Water Conservancy Boards To Facilitate Water Rights Transfers

The State Legislature recently authorized the formation of Water Conservancy Boards to allow local review and approval of water rights transfer applications. This option is a water conservation measure as the transfer of water rights can facilitate the more efficient use of existing water rights and potentially reduce the need for additional water supplies for municipal.

4.7.8 Improve Water Measurement Network

This option of improving the network of streamflow and groundwater monitoring stations is a water conservation option as the data collected will provide the basis for implementing the other water conservation measures and will provide data for the public to better understand the need for conserving water.

4.7.9 Implement Water Conservation At Port Townsend Paper Company

The Port Townsend Paper Company has studied the potential for reducing water use at the mill. The water conservation options studied could be implemented sooner than planned to reduce water diversions from the Big Quilcene and Little Quilcene Rivers.

5. HABITAT AND STOCK ASSESSMENT

5.1 PURPOSE AND SCOPE

This assessment begins with a brief summary of the status of salmonid fish populations in WRIA 17, focusing primarily on coho salmon and summer chum salmon due to the historical management focus on these species. Their status is largely inferred from the recent trend in spawning escapement, which is a limited perspective on the current health of a given fish population or stock[3]. Ideally, the status of a local fish population should be assessed from knowledge of its productivity (i.e. the number of juveniles that are born to each generation and survive until they migrate to the ocean, as well as the total number of returning adults). Generally speaking, this level of information is not available for salmonids in specific sub-basins in WRIA 17, except for Snow Creek (see below). Though a great deal of anecdotal information has been collected to describe the distribution of juvenile salmonids (particularly coho salmon) in WRIA 17, their abundance, or the recent annual variation in abundance, is not currently known.

The habitat assessment describes the quality of stream habitat that supports anadromous and resident salmonid fish in WRIA 17. A substantial body of published studies and gray literature (e.g. technical reports from resource agencies), are cited in this assessment. The intent is to provide a concise and accurate description of habitat quality in each sub-basin, by drawing primarily from standardized, and to the extent possible, quantitative survey results. Because different techniques and assessment protocols have been used in the various sub-basins, the quality of the resulting products is also assessed. In each sub-basin a summary of limiting factors is derived, either directly from studies that have reached those conclusions, or by drawing inferences from survey results (refer to Chapters 8 through 17). The historic and current range of species are also compared, with current distribution mapped in Exhibit 18.

5.2 HABITAT DATA CONSIDERATIONS

This summary of habitat information focuses on the stream segment classification used by the most recent, and usually the most rigorous, surveys. Various survey protocols have been used in different sub-basins. The analyses range in method and quality from inferred channel characteristics based on gradient and geomorphology to examination of aerial photographs and field assessments. The highest quality information is summarized for each sub-basin, referring to other information to the extent that it has been found reliable and detailed.

Detailed quantitative and qualitative descriptions of habitat exist for most of the principal salmonid-bearing streams in WRIA 17 in those reaches accessed by anadromous species. Though habitat surveys have been conducted under various protocols for many years, this document summarizes only the most recent, and what the authors judged to be the most accurate, surveys and assessments. This body of information is relevant to all salmonid species; however, it has focused primarily on the particular habitat requirements and degradation of habitat of summer chum salmon and coho salmon. Because these species are the focus of management, the abundance trends of these species are also better understood than for other salmonids.

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[3] The usual biological meaning of "stock", i.e., is defined for this report as a reproductively isolated, self-perpetuating population. In this context, salmon produced in a single basin or watershed complex are referred to as a stock.

Because historical data is generally lacking, the current extent and quality of habitat cannot, for most sub-basins, be quantitatively compared with historic or pristine conditions. Watershed analyses have, however, qualitatively characterized pre-settlement conditions, and natural processes that influenced habitat in the Big Quilcene River and Snow Creek / Salmon Creek basins. For specific reaches in the Big Quilcene, examination of old and recent aerial photographs have enabled a detailed description of channel changes. An exhaustive, and to the extent possible quantitative, comparison of pristine and current habitat conditions was also conducted in the Chimacum Creek system, using old General Land Office Maps and extensive interviews with elderly residents.

5.3 OVERVIEW OF SALMONID STOCKS IN WRIA 17

The recent trend in the abundance of salmon that originate in WRIA 17 can best be described by the number of adults returning annually to spawn. Salmon spawning escapement is estimated annually by WDFW and tribal fisheries management biologists. Index reaches in certain streams are surveyed repeatedly throughout the spawning season to count either live and dead adults or redds (nests). For coho salmon, these index counts, which represent a proportion of the total spawning habitat, are referenced to index reach counts in a base period, to estimate total escapement to the Hood Canal and Eastern Strait of Juan de Fuca regions. This regional estimate is apportioned to northern and southern Hood Canal according to estimates of total spawning habitat available in each zone. A separate regional estimate is made for streams entering Quilcene and Dabob Bays. Because of heightened concern over summer chum salmon stocks in the region, including those originating in six streams in WRIA 17, escapement to individual sub-basins is estimated annually (see below for details of methodology). Complementing the stream survey data, adult counts of coho salmon, and summer and fall chum salmon are made at the QNFH; these species and steelhead are also enumerated at the Snow Creek weir. Supplemental stream surveys have also been conducted, outside of the standard index reaches, which assist in describing the current distribution of fall spawning salmonids, but have not generated estimates of escapement to individual streams.

The WDFW Snow Creek Research Station, however, has generated detailed data that describes the survival and productivity of coho salmon and steelhead in Snow Creek. Accurate counts of returning adult coho salmon, age 0 parr, and outmigrant smolts, for example, provide the data necessary for detailed analysis of freshwater recruitment. The Snow Creek data is believed to provide very accurate and useful information that characterizes coho salmon production in eastern Strait of Juan de Fuca streams. A similarly intensive research effort at Big Beef Creek (located in WRIA 15) is used to characterize the annual variation in freshwater survival in Hood Canal. It is recognized that the topography, climate, and hydrology that affect streams draining the Kitsap Peninsula may differ substantially from conditions in streams draining the eastern Olympic Mountains.

The Endangered Species Act (ESA) listing of summer chum salmon from Hood Canal and the eastern Strait region has prompted theoretical analysis of the long-term viability of this group of severely depressed stocks. The total population size (average escapement multiplied by generation length) and the effective population size (effective number of breeders per year multiplied times the generation length) are measures of the ability of stocks to recover from low abundance. Effective population thresholds of 50 and 500 have been suggested as points below which significant loss of genetic variation and adaptive potential might occur (Thompson 1991).

The status of all salmon stocks in Puget Sound and the Washington coast was assessed by WDFW and tribal resource management agencies ten years ago (WDF et al. 1993). The conclusions of this inventory are summarized in Table 5-1. For some species, the SASSI assessment aggregated salmon stocks from a

region, e.g. Hood Canal summer/fall chinook salmon. The status of chinook salmon has since been re-assessed in greater detail by the NMFS status review (Myer et al. 1998) that was completed prior to their listing decision. The status of coho salmon and fall chum salmon stocks from small streams in other regions was not addressed, e.g. in independent streams draining the west shores of Hood Canal, north of Dabob Bay. The status of summer chum salmon stocks was re-examined in much greater detail by the NMFS status review (Johnson et al. 1997) and in the state/tribal Recovery Initiative (Ames et al. 2000). The status of winter steelhead stocks in WRIA 17 has not been re-assessed since the SASSI document was issued.

Table 5-1. The Status of Hood Canal and Strait of Juan de Fuca Salmon and Steelhead Stocks in WRIA 17 as Determined by the Salmon and Steelhead Stock Inventory and Assessment (WDF et al. 1993)

Stock	Status
Hood Canal summer fall chinook salmon	Healthy
Hood Canal summer chum salmon	Critical, due to low escapement
Western Hood Canal fall chum salmon	Healthy
Quilcene / Dabob fall chum salmon	Healthy
Quilcene / Dabob coho salmon	Depressed – chronically low escapement
Quilcene / Dabob winter steelhead	Unknown
Discovery Bay summer chum salmon	Critical – Short term severe decline in escapement
Sequim Bay summer chum salmon	Depressed – Short term severe decline in escapement
Chimacum coho salmon	Healthy
Discovery Bay coho salmon	Critical – short term severe decline in escapement
Sequim Bay coho salmon	Depressed – short term severe decline in escapement
Discovery Bay winter steelhead	Depressed – short term severe decline in escapement
Sequim Bay winter steelhead	Unknown

Coastal cutthroat trout populations from Hood Canal and the eastern Strait of Juan de Fuca (east of the Elwha River) were included in the Puget Sound Ecologically Significant Unit (ESU) after review by NMFS (Johnson et al. 1999). They concluded that the Puget Sound ESU did not warrant listing (NMFS 1999). No abundance information from WRIA 17 streams was considered in this review. The abundance of anadromous and resident cutthroat trout throughout the Hood Canal/eastern Strait region is largely unquantified, and specific population trends are unknown, except in Snow Creek. WDFW concluded that the status of bull trout populations in Hood Canal was unknown in their SASI appendix (WDFW 1998) that reviewed data from all populations in Washington.

5.4 SPECIES ACCOUNTS

5.4.1 Summer Chum Salmon

5.4.1.1 *Life History*

Summer chum salmon that originate in the streams of WRIA 17 are part of a genetically and behaviorly unique group of chum salmon populations that exhibit relatively early migration timing and that have adapted to the climatic and hydrologic conditions that characterize this region. While considering the status of all chum salmon populations in Washington, the National Marine Fisheries Service (Johnson et al. 1997) concluded that summer chum salmon from Hood Canal and the Eastern Strait of Juan de Fuca

comprised a unique Evolutionarily Significant Unit (ESU). After evaluating their risk of extinction, NMFS listed this ESU as threatened (NMFS 1998). In WRIA 17, this ESU includes summer chum salmon populations in the Big Quilcene River, Little Quilcene River, Snow Creek, Salmon Creek, and Jimmycomelately Creek, and the recently re-introduced stock in Chimacum Creek. Evidence is strong that these streams also represent the full historic distribution of summer chum salmon in WRIA 17 (Ames et al. 2000).

A general life history of summer chum salmon is reiterated below, noting factors that distinguish the WRIA 17 stocks. At the end of their three- to five-year oceanic migration in the North Pacific, adult summer chum salmon pass through the Strait of Juan de Fuca and into Hood Canal in August and September. They are predominantly three or four years old at maturity, with a small age-two and age-five component. In some areas, e.g. Quilcene Bay, they may mill at the mouth of their natal streams for ten to twelve days before entering freshwater from mid-August to mid-October. Run timing analysis for the Big Quilcene stock shows that the central 80 percent of the run enters the river between September 11th and October 14th (Ames et al. 2000).

Spawning occurs in lower stream reaches from late August through late October, and generally peaks in late September or early October. Eggs reach the eyed stage after four to six weeks, and hatch after eight weeks. Alevins develop in the gravel for another ten to twelve weeks before emerging between February and the end of May. Peak emergence for Hood Canal and Strait of Juan de Fuca populations is between March 22 and April 4. Development is somewhat slower in the Strait streams because of generally colder stream temperature. By contrast, fall chum salmon emerge from late-April to the end of May. In Big Beef Creek (west Kitsap Peninsula) 50 percent of fry had emerged after 166 days in the gravel (Koski 1981); the central 80 percent of emergence occurred between February 7th and April 4th (Tynan 1997). At the Quilcene Hatchery, 100 percent swim up was reported within 111 days after fertilization (Telles 1996 cited in Ames et al. 2000). Quilcene Hatchery diverts water from Penny Creek, the temperature of which is slightly warmer and less variable than the Big Quilcene River, where development of chum salmon embryos would be correspondingly slower.

Post emergent fry migrate immediately downstream to the estuary. They form dense schools, closely oriented to shore during the day, which disperse at night. Their nearshore orientation, in shallow water, persists until fry reach 45 to 50 mm, after which they move into deeper water in the neritic zone. They are often found in close association with eelgrass beds, which provide cover and forage. The early marine migration may be interrupted for several days by residence in the productive deltas at the mouths of larger streams and rivers.

5.4.1.2 *Stock Assessment Tools*

The historical trends in the abundance of summer chum salmon stocks is inferred from their spawning escapement, and from estimates of annual abundance which result from reconstruction of their catch distribution added to escapement. Spawning escapement is estimated from field surveys that count live and dead fish on the spawning grounds. The number of miles of stream surveyed for summer chum salmon has increased in recent years, with resulting improvement in the accuracy of estimates. There were few summer chum salmon surveys prior to 1952. From 1952 to 1963 WDFW surveyed seven miles of spawning habitat, then doubled that effort to 14 miles from 1964 to 1973. After the Boldt Decision, the demand for more accurate estimates motivated a further increase in effort to 65 stream miles from 1974 to 1980. Prior to 1974 surveys indexed spawning escapement, which is to say that counts in representative stream reaches were compared to those in a reference year, and expanded to a total estimate. Subsequent effort increased the survey mileage to 107 miles in Hood Canal and the Strait of

Juan de Fuca, and counts of live chum salmon were made every seven to ten days in order to plot an escapement curve over time. Having accounted for the average residence time of an individual fish, the area under this curve can be used to compute total escapement. Supplementing these survey data, which in WRIA 17 are done in the lower Big Quilcene River, summer chum salmon are also individually counted at the QNFH and at Snow Creek, where traps (racks) are monitored to enumerate escapement (Ames et al. 2000).

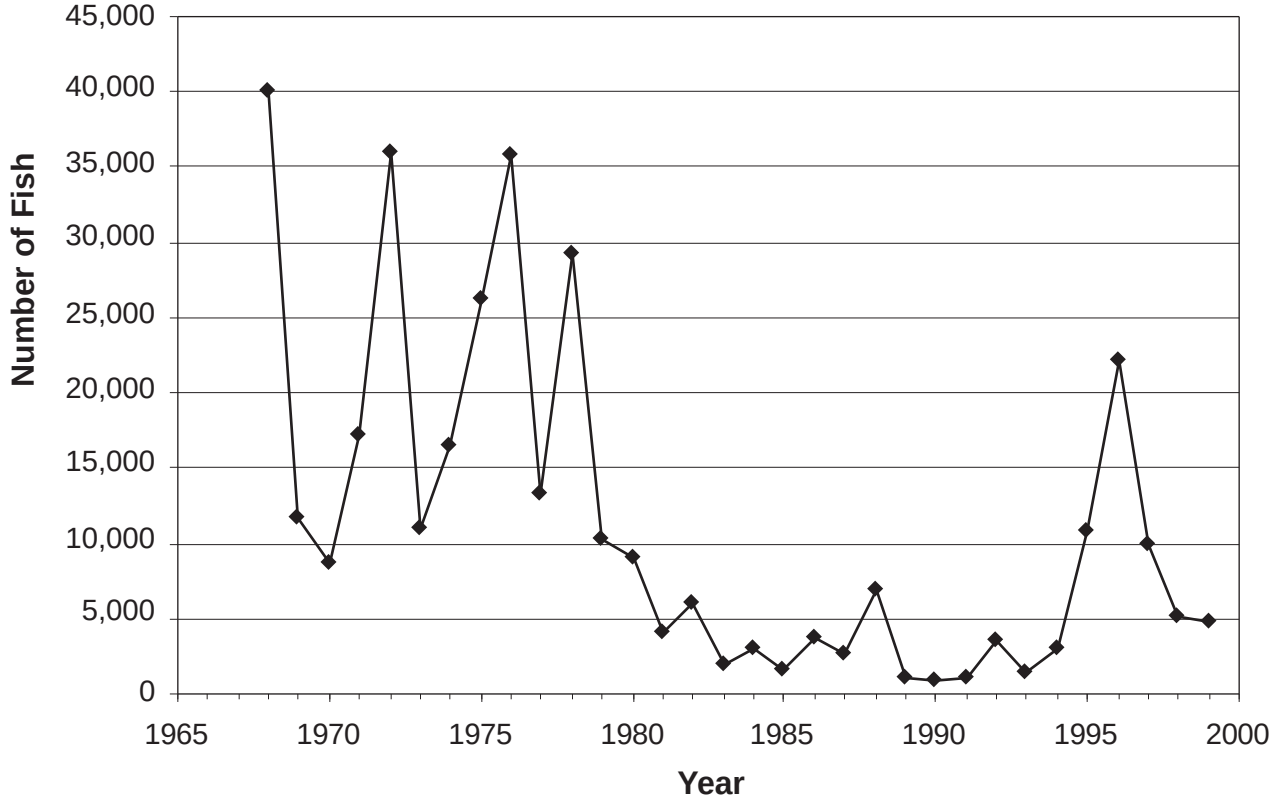
Run reconstruction allocates the catch in each fishing area to its constituent stock aggregates, based on their relative abundance. Spawning escapement may provide relative abundance, or catch may be sampled directly and apportioned by genetic analysis or coded-wire tags. The central problem is accurately differentiating summer chum salmon from the more abundant fall chum salmon that also originate in Hood Canal. With few genetic- or tag-based analyses available, the migration timing of summer and fall chum salmon was carefully re-examined, and cut-off dates assigned to each fishing area to delineate the presence of summer and fall chum salmon. Catch in the Canadian fisheries in the Strait of Juan de Fuca are also accounted by using genetic analyses of samples collected in the 1996 to 1998 period. By these means all fisheries harvest which likely intercept summer chum salmon is estimated, and added to spawning escapement to yield estimates of the total abundance of summer chum salmon returning to Hood Canal and to the Eastern Strait of Juan de Fuca. More detailed stock resolution is not yet possible. Insufficient data is available to accurately determine the age composition of annual summer chum salmon returns, which would enable the estimation of the survival rates for each brood year, and the number of recruits per spawner. Effort to collect and read the scale samples necessary for this important analysis has increased in recent years.

5.4.1.3 *Abundance Trend for Hood Canal and Strait of Juan de Fuca Summer Chum Salmon*

The abundance trends for Hood Canal and Eastern Strait of Juan de Fuca summer chum salmon differ, though abundance in both regions has declined. Populations are impacted by different habitat stresses and harvest rates. In general, the Hood Canal stocks started to decline in 1979, while the Strait stocks declined ten years later. These trends are demonstrated from five-year average spawning escapement and total abundance data. Between 1974-1978 and 1979-83, average escapement for Hood Canal stocks dropped by 80 percent (Table 5-2). This decline continued into the early 1990's, with the 1989 through 1993 average escapement dropping to 1,037, and to a low escapement of 429 in 1990 (Figure 5-2). Total run size dropped concurrently, and originated with strong brood escapement in 1975 and 1976 escapement, so the decline has been attributed to declining ocean survival combined with overfishing and habitat degredation. The stocks of Big Quilcene, Duckabush, and Dose Wallips Rivers recovered dramatically in 1995 through 1997, then declined somewhat in 1998 and 1999 (Figure 5-1). The stocks did not significantly increase in other rivers of Hood Canal between 1994 and 1996. Much of this recovery is attributed to the stock recovery program initiated at the QNFH, but escapement for some other stocks has also increased. However, escapement to the Little Quilcene River has remained quite low, and was less than 100 in 1995, 1997, and 1999.

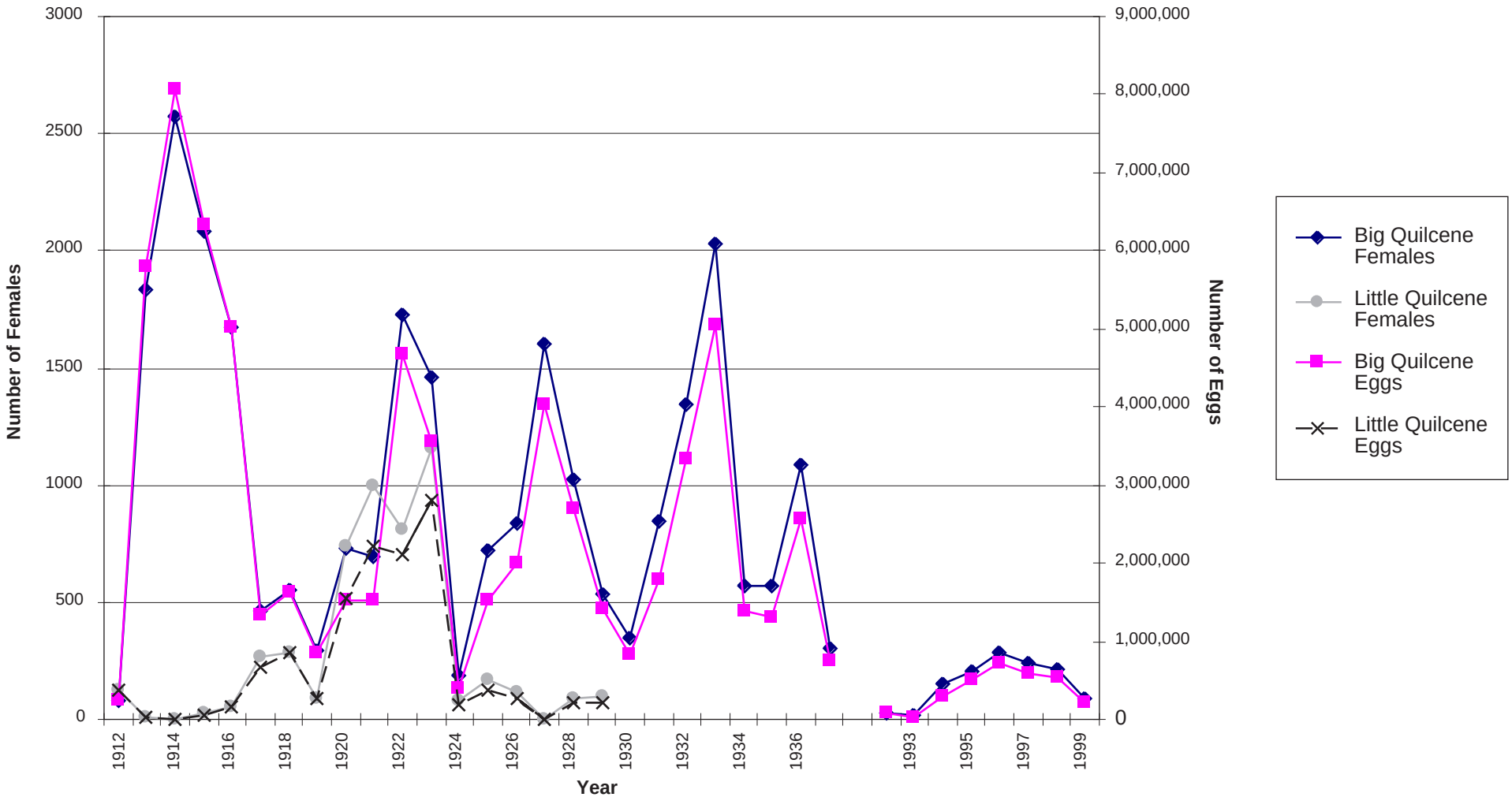
Table 5-2. Five-year Average Spawning Escapement and Total Abundance for Hood Canal Summer Chum salmon Stocks (from Ames et al. 2000)

Return Years	Escapement	Total Abundance
1974-78	17,727	32,031
1979-83	3,238	8,038
1984-88	1,760	5,054
1989-93	1,037	2,493
1994-98	8,509	9,512



Source: Ames et al., 2000.

Figure 5-1
Total Spawning Escapement of Hood Canal and Eastern Strait of Juan de Fuca Summer Chum Stocks, 1968-1998



Source: I. Jablonski, City of Port Townsend, 2000 (personal communication).

Note: USFWS operated fish weirs near the river mouths between 1912 and 1937, whereas fish spawned in the 1990s were mostly collected from fishermen on the bay.

Figure 5-2
Summer Chum Broodstock Collection at the Quilcene National Hatchery, 1912-1999

The Strait stocks declined by a factor of three, beginning in 1989 (Table 5-3). The average escapement in 1984-88 was 1,716, and dropped to 513 for 1989-93. Total run size fell concurrently, again suggesting a decline in ocean survival. The increase in the abundance for Hood Canal stocks has not been mirrored in the Strait stocks. Snow Creek escapement increased and remained stronger in 1996-98, then fell below 500 in 1999. Escapement to Salmon Creek increased in 1996, but has been below 100 in subsequent years. Jimmycomelately Creek recovered in 1995, but has since declined to very low number (seven in 1999).

Table 5-3. Five Year Average Spawning Escapement and Total Abundance for Strait of Juan De Fuca Summer Chum Salmon Stocks (from PNTPC et al. 1999)

Return Years	Escapement	Total Abundance
1974-78	1,881	2,087
1979-83	2,128	2,475
1984-88	1,716	1,929
1989-93	513	757
1994-98	796	898

5.4.1.4 *Extinction Risk*

The Hood Canal/Eastern Strait of Juan de Fuca Summer Chum Salmon Recovery Plan (Ames et al. 2000) includes a discussion of the likelihood of extinction for the various summer chum salmon stocks in the ESU. Extinction risk is evaluated from the effective population size (i.e. the effective number of breeders per year multiplied by the generation length of 3.6 years) of individual stocks. Various authors have estimated that a critical threshold for effective population size is in the range of 50 (Allendorf and Ryman 1987) to 500 (Nelson and Soule 1987). The 50/500 rule of thumb provides a short-term effective population size, where the 50-population number prevents an unacceptable rate of inbreeding (N_e) and the 500-number maintains a long-term overall genetic variability (N_e) (Thompson 1991). Since random mating may not occur in nature, to reach a minimum viable actual or census population that ensures a random union of males and females (N), the actual number of returning adult fish is likely to be 100-500 (short term N_e)/1000-5000 (long-term N_e). Extinction risk is a highly theoretical concept. Critical thresholds of abundance are likely to evolve as more research on the genetic resilience of Pacific salmon is applied.

5.4.2 Fall Chum Salmon

5.4.2.1 *Life History*

Fall chum salmon share the same general freshwater and marine life history patterns as discussed above for summer chum salmon, but differ in their migration and freshwater entry timing. Fall chum salmon stocks in Hood Canal show two distinct migration timing patterns. The ‘normal’ stocks begin entering the terminal area of Hood Canal in early October, and are at peak abundance in their freshwater spawning streams at the end of November. By contrast the ‘late’ stocks show a peak of escapement timing in mid-December and continue to spawn through early January. In streams in Hood Canal that support summer and fall chum salmon stocks, the fall stocks show ‘late’ return timing. There is some evidence that these late stocks tend to spawn higher in the drainages than summer chum salmon (Lampsakis personal communication).

5.4.2.2 *Stock Status*

In general fall chum salmon stocks in Hood Canal are healthy and productive, with spawning escapement averaging 100,000 since 1990. Stocks that originate in streams draining the northwestern shores of Hood Canal comprise a relatively small proportion of the total production in Hood Canal, and few fall chum salmon are produced in streams in the western Strait of Juan de Fuca, and Chimacum Creek. In northern Hood Canal (including streams draining from the northern Kitsap Peninsula) fall chum salmon escapement has ranged between 1,000 and 3,000, and has shown an increasing trend, since 1990 (Figure 5-3). The Big Quilcene and Little Quilcene Rivers, and other smaller tributaries that drain into Quilcene Bay and Dabob Bay, contribute a more significant proportion of fall chum salmon returning to Hood Canal. Aggregate spawning escapement into Quilcene Bay streams has been less than 5,000 for most years since 1990, but in 1995 to 1997 it ranged between 10,000 and 25,000 (Figure 5-3). Spawning escapement is not estimated for any single stream in WRIA 17, but index reaches are surveyed in the Big Quilcene River, Jackson Creek, Spencer Creek, the Little Quilcene River, Snow Creek, Salmon Creek, and Jimmycomelately Creek.

The resulting data contribute to the calculation of regional estimates of escapement. Additional data are gathered from supplemental surveys in other small streams, and from the counting weirs at the Quilcene National Fish Hatchery and Snow Creek. Surveys to describe the distribution of spawning coho salmon have noted fall chum salmon spawning in Tarboo Creek, Thorndyke Creek, Shine Creek, and Chimcacum Creek (Bahls 1995, 1996, 1997b); these occurrences are further described below for each sub-basin.

5.4.3 Coho Salmon

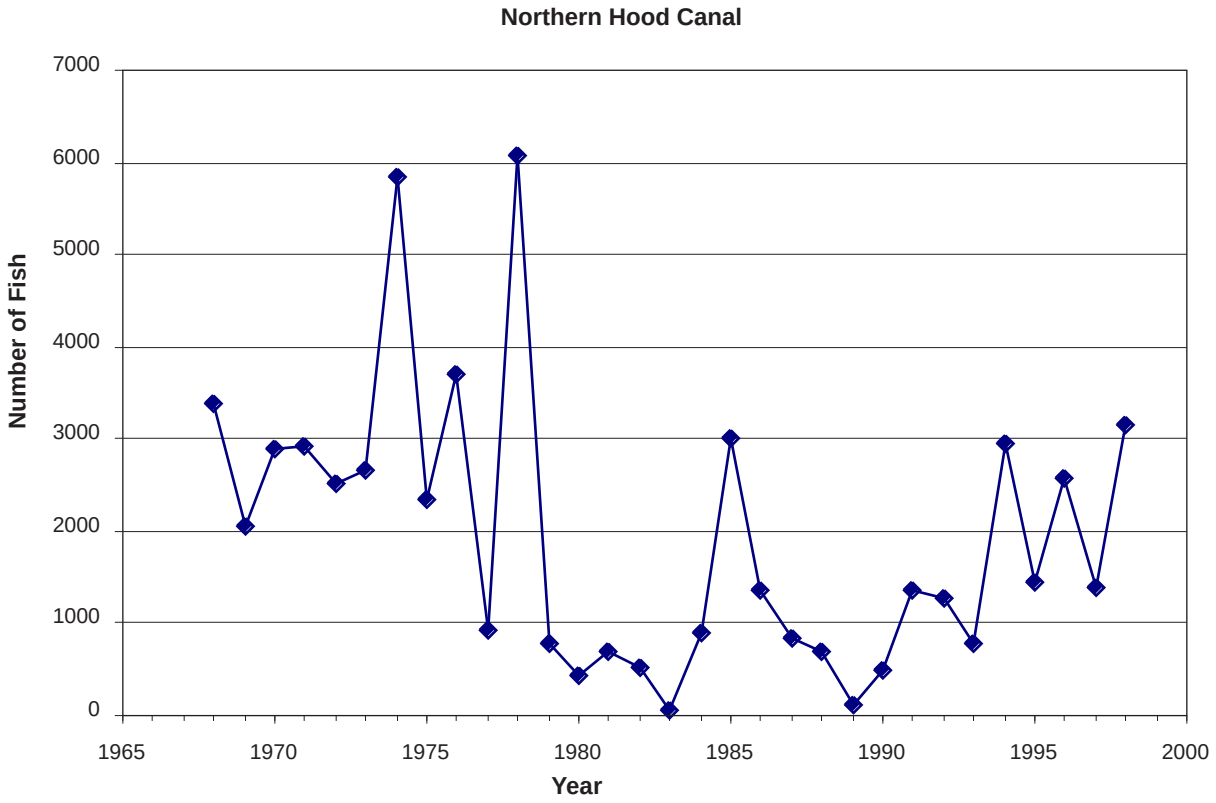
5.4.3.1 *Coho Salmon Life History*

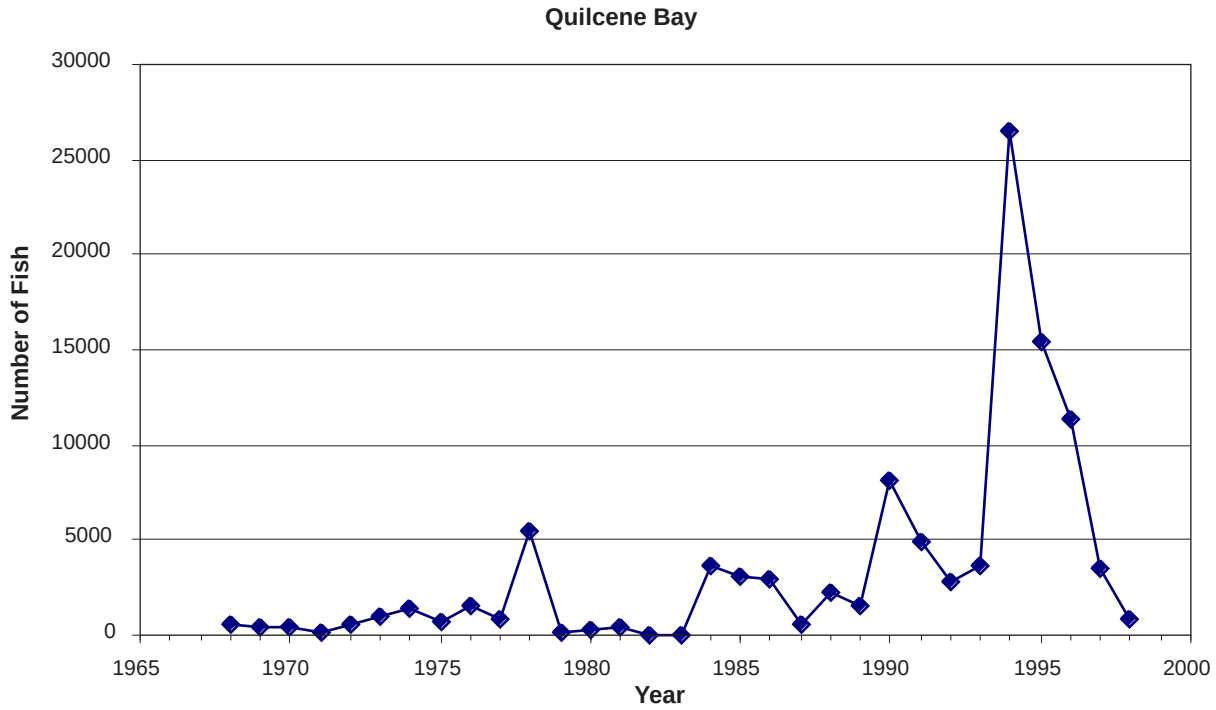
Adult coho salmon return to natal streams in Hood Canal and the Strait of Juan de Fuca after a year-long oceanic migration along the coasts of Washington and southern British Columbia. They pass through the Strait primarily in late August and September, and enter freshwater from October through mid-December. Spawning occurs into January. Eggs hatch in eight to 12 weeks, then remain in the gravel for an additional four to ten weeks. Fry begin to emerge from redds in early March, and generally rear in freshwater for a year. As fry develop and grow they become territorial. Their diet is predominantly aquatic and terrestrial insects, and may include small fish later in the freshwater phase. Smolts migrate out of the streams into marine areas from between February and April of their second year. Although a significant number of males mature precociously, and return to their natal system in the fall of their second year, adults are primarily three years old when they return to spawn.

5.4.3.2 *Coho Salmon Stock Delineation*

Naturally reproducing fall coho salmon originating in the different sub-basins of WRIA 17 are generally treated as separate stocks, except that Big Quilcene and Little Quilcene production comprises a single stock. Genetic analyses, such as the allozyme-based studies of summer chum salmon, have not been used to differentiate Puget Sound coho salmon stocks. Fisheries managers classify the stocks into broader management units. Coho salmon returning to Quilcene Bay and Dabob Bay streams are managed together, as are stocks returning to all northern Hood Canal streams, and the aggregate of stocks returning to Sequim Bay, Discovery Bay, and Chimacum Creek.

In the following discussion the status of individual stocks, rather than management units, is summarized to the extent possible, with the more regional perspective of management units added where spawning escapement and productivity trends are applied to fisheries management decisions.





Source: WDFW/NWIFC run reconstruction database.

Figure 5-3
Fall Chum Salmon Spawning Escapement to Northern Hood Canal and Quilcene Bay Streams, 1968-1998

5.4.3.3 *Coho Salmon Abundance Trends in WRIA 17*

Natural coho salmon spawning escapement to Hood Canal systems, except the Skokomish River (for which an independent estimate is made), is estimated in the aggregate from annual survey of index reaches in the major coho salmon production areas. The estimate of total natural escapement is apportioned into northern and southern zones according to the total spawning habitat available in the streams in each zone. The northern zone, which includes streams north of the Dosewallips River on the west shore, and north of Anderson Creek on the east shore, is presumed to have approximately 48 percent of the total spawning habitat. Escapement to northern Hood Canal streams has shown an increasing trend, from an average of 6,300 from 1987 to 1993, to an average of 26,600 for 1994 to 1998 (Figure 5-4). Improving freshwater and marine survival, and reduced harvest pressure, contributed to this increase in escapement. Whether this trend will persist is uncertain. Preliminary escapement estimates for 1999 suggest a dramatic decline (Sawicki personal communication). The smaller independent northern Hood Canal streams in WRIA 17 do not currently contribute a significant proportion of the region's coho salmon production, but their potential production could be substantially higher if habitat quality improved.

5.4.4 Chinook Salmon

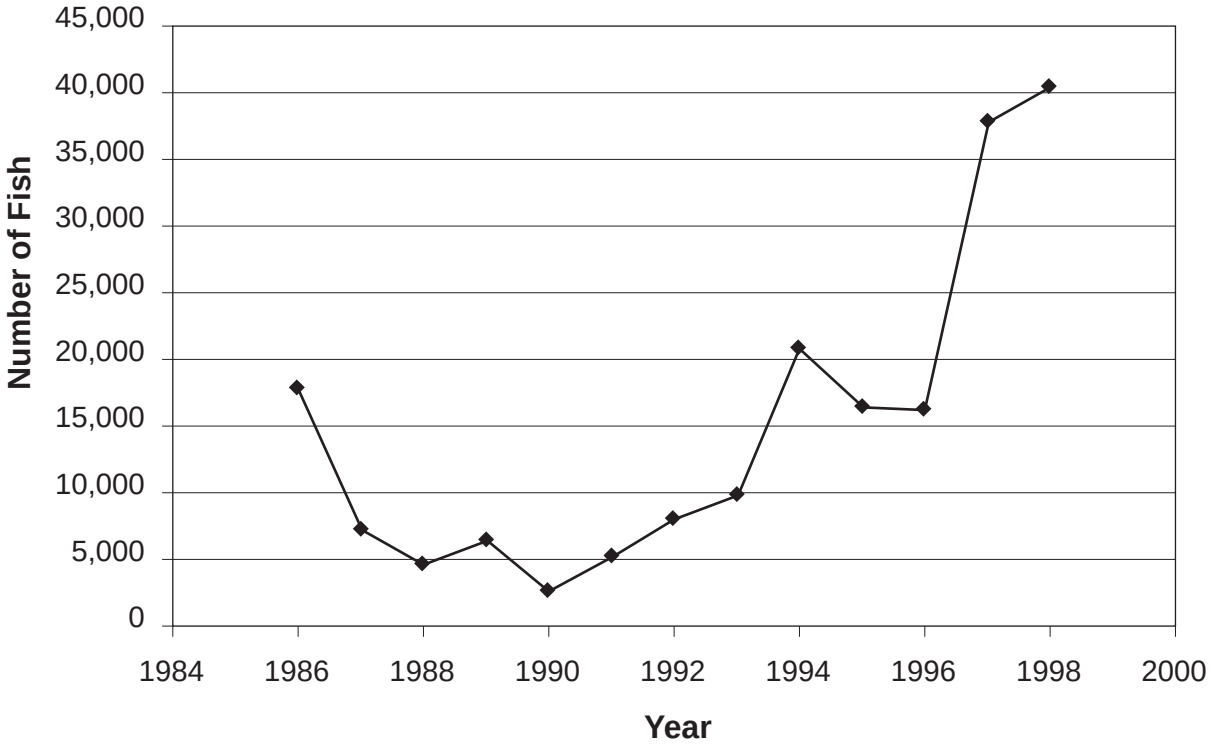
Chinook salmon that currently return to streams in WRIA 17 are predominantly strays from enhancement programs or natural production in other systems in Hood Canal and Puget Sound. There is anecdotal evidence suggesting that the Big Quilcene River, at one time, supported a native run of fall chinook salmon. The Quilcene Hatchery produced fall chinook salmon in the 1960's and 1970's from broodstock imported from several Puget Sound hatchery programs, but the survival of these releases was never high enough to provide significant fisheries enhancement or generate a self-sustaining program at Quilcene. Spring chinook salmon were also raised at the Quilcene Hatchery, beginning in 1978, using imported broodstock, but this program was discontinued, for the same reason, in 1996.

As noted below in descriptions of individual sub-basin fisheries, adult chinook salmon are still occasionally noted at the Quilcene Hatchery rack, the Snow Creek weir, and during spawning surveys in other WRIA 17 streams (e.g. Tarboo Creek, Salmon Creek). Juvenile chinook salmon produced in other Hood Canal systems pass through the sub-estuaries at the mouths of WRIA 17 streams, which comprise vitally important habitat for these other stocks. Freshwater habitat recovery efforts, particularly those in the Big Quilcene River, could consider the potential for systems to support chinook salmon production in the future.

5.4.5 Steelhead

Winter steelhead return to many of the streams and rivers in WRIA 17. With the exception of the Snow Creek stock, where a WDFW research station has collected data on escapement and smolt production since 1978, very little is known about recent trends in steelhead abundance or productivity. However, most populations in the Eastern Strait of Juan de Fuca and Hood Canal are thought to be depressed (McHenry et al. 1996).

Winter steelhead spawn from February through early May. Fry emerge from the gravel from mid-June to mid-August. Juvenile steelhead rear for one or two years in freshwater before outmigrating to begin their marine existence. Adults return to freshwater to spawn after one or two years, and unlike the five species of Pacific salmon, at least a part of the population are repeat spawners. Their life expectancy is 6 to 9 years (Lichatowich 1993a).



Source: Hood Canal Joint Tech. Comm., 1999.

Figure 5-4
Spawning Escapement of Coho Salmon in Northern Hood Canal Streams, 1986-1999

The following detailed life history information has been gathered from WDFW's Snow Creek station. Adults return to Snow Creek from early February through April, with a peak in late-March to mid-April (Johnson and Cooper 1986b). Sexually mature adults spend about two months in the stream, spawning and then returning to the ocean. The median interval between spawning and emergence is about 70 days. In August of their first summer in freshwater, juvenile steelhead average 58 mm in length and weigh 2.5 grams. One year later they average 116 mm in length and weigh 20 grams. Smolt outmigration begins in April and continues through mid-June. Most smolts (84.5 percent) are two years old when they emigrate; 9.8 percent are age 1, and 6.7 percent are age 3 (Johnson and Cooper 1993).

5.4.6 Coastal Cutthroat Trout

Anadromous and resident populations of coastal cutthroat trout are distributed throughout the streams of WRIA 17. Spawning occurs from February to May, and alevins emerge from the stream substrate from April through August. Juvenile cutthroat feed primarily on larval aquatic and terrestrial insects. Anadromous juvenile fish undergo the smolt transformation in their second or third year. They become sexually mature at two to four years of age, and re-enter freshwater in the autumn and winter prior to spawning. Adult cutthroat will typically spawn repeatedly over the course of their adult lives. Because of the WDFW research program, there is more information on Snow Creek cutthroat life history than for other streams in WRIA 17. Quantitative estimates of the abundance of resident or anadromous forms is typically lacking for other WRIA 17 streams.

5.4.7 Bull Trout

The current distribution of bull trout (*Salvelinus confluentus*) in WRIA 17 streams is not known (WDFW 1998), but based on their habitat requirements, they are not likely to be found in the low-elevation streams that typify most of this region. The upper Big Quilcene River probably provides the most likely potential habitat for bull trout. Limited hook-and-line sampling in the Big Quilcene (Donald 1991) did not detect any bull trout. Although two bull trout/Dolly Varden were reported in the Big Quilcene River in 1992, none have been trapped at the Quilcene National Fish Hatchery in recent years, nor have any been observed in recent snorkel surveys conducted by WDFW and U.S. Forest Service biologists. Consequently, the WDFW does not believe that there is a distinct bull trout/Dolly Varden stock in the Big Quilcene River (WDFW 1998). The closest known extant population occupies Cushman Lake and the upper North Fork Skokomish River, which drains into southern Hood Canal. Bull trout require relatively cold water for successful spawning (9 to 10 ^{o}C), incubation (2 to 4 ^{o}C) , and rearing (4 to 10 ^{o}C) (cited in USFWS 1998). Lower elevation reaches that exceed this preferred temperature may still provide a migration corridor, particularly where anadromous populations exist, if suitable habitat is accessible higher in the watershed. In other aspects of habitat, bull trout requirements are similar to other salmonids. They depend on complex stream channels, with deep pools and adequate cover. Cold water refugia, created by groundwater influx, must be connected to winter rearing and holding water, particularly for migratory (adfluvial) populations. Incubating eggs and pre-emergent alevins, which may reside more than 200 days in the substrate, are peculiarly sensitive to fine sediment loading.

5.5 HABITAT ASSESSMENT APPROACH AND METHODOLOGIES

5.5.1 Habitat Requirements of Salmonids Found in WRIA 17

The freshwater habitat requirements of salmonids found in WRIA 17 have been extensively reviewed elsewhere (e.g. Spence et al. 1996), and are not reiterated in detail in this document. Existing habitat assessments focus on the suitability of conditions for migration, spawning, incubation, and rearing by

species of primary concern (i.e. summer chum salmon and coho salmon). It is important to consider the requirements of WRIA 17 fish populations in light of the extraordinary environment to which they are adapted. Almost all of the streams have low-elevation headwaters and thus are dependent on precipitation and groundwater discharge to maintain stream flow through the summer. Rainfall in the shadow of the Olympic Mountains is low in comparison with the surrounding regions of Puget Sound, so stream flow naturally declines substantially in the summer and fall. Because their environment is in many respects marginal, these populations are uniquely vulnerable to habitat degradation (Lichatowich 1993a).

Summer chum salmon are particularly susceptible to reduced base flow (i.e. the low stream discharge typical of late summer and early fall) because they enter freshwater and spawn earlier than other salmonids. Low flow can delay or limit access to preferred spawning sites, forcing utilization of sub-optimum sites at which egg survival is lower (Ames and Beecher 1995 cited in Ames et al. 2000). Chinook salmon are also susceptible since they may enter streams in early fall. Low flow affects the ability of adults to access suitable spawning habitat, the availability of holding pools in which they undergo final maturation, as well as the area of habitat available. Summer low flow also affects juvenile coho salmon, steelhead, and chinook salmon, and other summer-rearing species, particularly in aggraded channels and where pool habitat is limited by lack of LWD. Some reaches of many lower order streams in WRIA 17 dewater at base flow, making them seasonally unsuitable for certain species and life stages.

Sediment loading and transport processes affect the quality of spawning habitat. Generally, deposition of excessive fine sediment prevents an adequate flow of oxygenated water over the incubating eggs. Excessive coarse sediment loads can result in streambed aggradation which can entomb redds and affect the surface flow regime. A dysfunctional riparian zone and floodplain will allow the force of peak fall and winter flows to erode streambanks and the channel, and cause scouring of redds.

The characteristics of high quality summer and winter rearing habitat are similar for juvenile coho salmon, steelhead, and cutthroat, however their habitat preference will differ slightly in terms of temperature tolerance, substrate, current velocity, and elevation (Johnson and Cooper 1986b). The availability of pools, and the fluvial processes and riparian conditions which promote the maintenance and development of large, deep pools, are of over-riding importance to all species. High quality pool habitat is related to several concurrent processes that promote physical complexity in the stream channel, appropriate physical and chemical water quality, prey production, and security from predators.

A functional connection between streams and their sub-estuaries is essential to assure that suitable habitat exists when juvenile salmon are making the transition from freshwater to marine areas. The integrity of the delta and sub-estuarine zone is closely linked to processes in the upper watershed that affect sediment transport and stream flow. Intertidal side channel and slough habitat that facilitates the migration of juvenile fish to the estuary is required as they undergo the physiological changes associated with adapting to saltwater. Productive and secure estuarine habitat, including eelgrass beds, is particularly essential to juvenile chum salmon survival, because it provides a highly specialized diet and security from predation (Simenstad in Ames et al. 2000).

5.5.2 Assessment Methodologies

Habitat survey protocols have evolved steadily over the last 20 years toward a more standardized and quantitative method. Most WRIA 17 streams have been well described by one or more of these methods, so that degraded habitat is delineated and the contributing watershed processes well defined. In general these assessments conclude that habitat that supports anadromous salmonid populations in all of the sub-basins is highly degraded and is currently limiting the potential for populations to recover. The various assessment protocols are described below, before presenting their detailed results in each sub-basin.

5.5.2.1 *TFW Protocol*

The objectives of the TFW assessment in WRIA 17, which was supported by a Centennial Clean Water Fund grant, were to:

- Describe the current condition of instream and riparian habitat.
- Monitor key physical and components ….. to determine trends in habitat conditions and relationships to land management activities.
- To assist watershed committees in developing management plans and determine the effectiveness of existing plans (Bernthal et al. 1999).

Project leaders selected streams in Hood Canal and the eastern Strait of Juan de Fuca region because of the presence of at-risk fish stocks, and their location with respect to non-point pollution management plans. Streams were divided into segments based on gradient, channel confinement, and tributary confluences. Permanent, surveyed reference points were established in each segment to characterize bankfull channel width, depth, and canopy closure; channel location (bank stability) and LWD were keyed to these reference points.

Stream flow was measured at the downstream end of each segment at the time of survey. The area of pools, tailouts, riffles, and cascades was measured. Pools were classified (Bisson et al. 1982; Nickelson et al. 1992), and pool depth and pool frequency determined.

The abundance, type, and function of LWD was characterized according to Schuett-Hames et al. (1994). The location and dimensions of all wood pieces greater than two feet long and 4.5 inches in diameter was determined. Wood type, stability, state of decay, orientation to the bank, and association with pools was described. Stable LWD, capable of retaining other wood, are defined as key pieces according to standardized dimension classes, relative to bankfull width.

For streams in WRIA 17, the substrate composition of the streambed was visually classified, based on Ralph (1990) and King County Surface Water Design Manual (1991). More intensive analysis of spawning area substrate, involving collection of samples, and separating and weighing different size classes of material was not performed for WRIA 17 streams.

Channel stability was described, with eroding banks measured and located. Predominant land use in the riparian area was also described. Vegetation in the riparian zone (i.e. a 30-m strip on each side of the channel), was categorized according to plant species and seral stage, and the segment characterized according the dominant category (Hall et al. 1992). The data for each parameter was rated using the indices of resource condition from the Washington State Watershed Analysis Methodology (WFPB 1992).

5.5.2.2 *The Watershed Analysis Protocol*

Watershed Analysis (WFPB 1992) is used to assess the effects of forestry management on fish and wildlife. The Big Quilcene Watershed Analysis (BQWAT 1994) confined its detailed scoring of habitat conditions to those reaches that support reproducing salmonid populations, outside of the Buckhorn Wilderness. These “locally significant habitats” included 11.42 km of the Big Quilcene River, all (7.1 km) of Penny Creek, 7.75 km of Townsend Creek, 1.5 km of Spencer Creek, 4.25 km of Jackson Creek,

and 2.5 km of Marple Creek. The following habitat variables were assessed: rearing pool area and frequency and adult holding pools, off channel rearing area, fish passage (adult and juvenile), large woody debris, substrate composition and scour. The assessments were based primarily on existing habitat surveys that had been conducted by the Forest Service in 1978, 1979, 1990, 1992, and the Washington Department of Game in 1977 and 1978. Existing habitat was compared to the following "target conditions" (Quinn and Petersen 1994):

- Large woody debris frequency: 2.03 - 2.44 pieces (at least 10 cm diameter by 2 m long) per reach length equal to the bankfull channel width;
- Pool area: 50 percent of the channel area;
- Fines: substrate should contain less than 11 percent of material less than 0.85 mm in diameter;

The habitat assessment is complemented by an assessment of channel morphology throughout the Big Quilcene Unit. Segments are classified as very low gradient (i.e. less than 1 percent) storage and transport, low gradient (i.e. one to four percent) storage and transport, steep (i.e. four to eight percent) storage and transport, very steep (i.e. 8 to 20 percent) transport, and very steep (i.e. 8 to 20 percent) confined cascades. For each gradient type the channel type and floodplain, influence of LWD, substrate type and transport processes, and peak flow effects are described. These assessments were based on examination of photographs and video, with substantial field verification.

5.5.2.3 *The EDT Protocol*

The Ecosystem Diagnosis and Treatment (EDT) analysis was applied to streams producing coho salmon in Hood Canal (PNPTC 1997) with the intent of developing guidelines and priorities for maintaining and restoring stream habitat. The analysis identifies habitat factors that determine coho salmon production through the phases of their freshwater life history. Stream reaches were generally delineated by the same criteria used by the TFW protocol, except that reach breaks were added at all tributary junctions. In general, parameters describing habitat condition were the same as the TFW protocol (see above). Information compiled on reaches included habitat unit type and dimension, water temperature, stream flow, substrate composition (percent fines), LWD, riparian condition, and adjacent land use. These attributes were determined from existing habitat survey data and from the personal knowledge of state, tribal, and federal agency biologists, local landowners, and other volunteers. The EDT process evaluated the functionality of each stream reach for each resident life stage of coho salmon, relative to the pristine habitat condition. The productivity (i.e. reproductive rate), capacity (fish density), and diversity of the subject streams were subjectively evaluated. The relative quality of a panel of attributes of habitat were evaluated by rating them in terms of productivity. These included channel stability, flow, habitat diversity, sediment load, temperature, riparian condition, presence of predators, toxic chemicals, competitors, barriers, nutrient load, dissolved oxygen, and pathogens. The total area available to each life stage was estimated for each reach. The proportion of the total habitat preferred or required for a given life stage was rated. The EDT process developed a complex graphical representation of these habitat attributes for each stream that was evaluated.

5.5.3 Limiting Factor Analyses

5.5.3.1 *Bahls and Rubin Limiting Factor Analysis*

Bahls and Rubin (1996) used a combination of the EDT process and TFW field survey methods to evaluate habitat limiting factors for coho salmon in the Chimacum watershed. Twenty two field sampling

stations were established along representative reaches throughout the watershed. Existing conditions were assessed by field monitoring of flows, stream temperature, dissolved oxygen, physical habitat characteristics and abundance of summer rearing fish at these stations and additional supplemental sites. Historical, (i.e. pre-settlement), conditions were reconstructed by studying General Land Office Surveys from the 1850s, oral history interviews with long time residents, field interpretation, and old maps (pre-flood control). Historic habitat quality and quantity was compared to existing conditions to determine the extent and location of habitat losses for each coho salmon life history stage (spawning, summer and winter rearing). Remaining high quality habitat areas, acting as strongholds for the population, were also identified. Protection and restoration recommendations, keyed to specific areas of the watershed, are provided. An evaluation of surface and groundwater withdrawals and effect on stream flows was not conducted as part of this analysis.

5.5.3.2 *Limiting Factors Analysis for Summer Chum Salmon*

The WDFW and Tribal biologists initiated a recovery planning process for Hood Canal and Eastern Strait of Juan de Fuca summer chum salmon in 1992, two years before the petition for their listing under the ESA was filed. The habitat recovery plan was drafted early in this process and was first released for public review in March 1999. Data compiled from a variety of published reports and gray literature (unpublished reports and data), and information from a large group of biologists with direct knowledge of freshwater habitat conditions, were evaluated to rate how a series of habitat factors have affected summer chum salmon production in each of the drainages where they currently exist. Factors included stream flow, water temperature, dissolved oxygen, substrate composition, LWD loading, channel condition and stability, riparian condition, floodplain and wetland loss, fish passage, estuarine and nearshore habitat condition. Effects on migration, spawning, incubation, and rearing were evaluated. Estuarine condition was separately assessed from recent aerial photographs, which enabled quantification of the areas affected by diking, filling, and road construction.

The resulting document is a comprehensive analysis of how habitat factors currently constrain summer chum salmon production in WRIA 17 and throughout the ESU. It is generally considered to be the definitive guide to prioritizing habitat protection and restoration efforts in the context of other recovery measures.

5.6 EVALUATION OF HABITAT DATA QUALITY

As part of the Stage I Watershed Technical Assessment, the WRIA 17 Planning Unit requested an evaluation of the quality of habitat assessment data in each sub-basin, and of its utility for future planning efforts, and possible merging with other spatial databases. It has been assumed that the primary goal of the Planning Unit was to have access to a concise abridgement of all habitat data that will be useful in planning habitat conservation and restoration, and be relevant to managing surface and groundwater resources. The following criteria were used to judge data quality in this summary.

- How recently were the data collected?
- Was the protocol standardized, replicable?
- Relative dependence on remote vs. field data collection
- Are watershed-scale processes evaluated
- How comprehensive was the data set in identifying key limiting factors?
- Does it provide a baseline against which to measure past or future change?
- Does it identify habitat protection and restoration opportunities

- Suitability for merging with SSHIAP or other comprehensive habitat database

Habitat assessment protocols have evolved steadily over the last 20 years, and continue to be refined and shaped to serve particular planning and research purposes. Their implementation is always to some degree constrained by time or funding. Two protocols (TFW and WA) have been employed in WRIA 17, that vary widely in scope and purpose. Their results are complemented by a large body of anecdotal comments that are associated with spawning surveys, flood control investigations, barrier inventories, and habitat restoration projects. Though clear, logical linkage may be drawn between habitat conditions and the potential for salmonids to reproduce successfully and thrive in a given stream, there is, as yet, no quantitative or predictive relationship between salmonid productivity and the suite of habitat quality parameters that are assessed. In considering even a single species or population, a complex of physical biological factors influence growth and survival at each life stage, with stochasticity marking each interaction. Therefore, the ability to quantitatively predict the consequences of future habitat improvement or deterioration, in terms of fish abundance, is an illusive goal.

Water temperature is frequently cited as the one of the most influential and often degraded qualities of habitat. Temperature preferences of different species are well described, as are the upper and lower lethal tolerance limits. However, a comprehensive data set, gathered from a number of fixed sampling locations, do not describe how fish respond to unfavorable temperature regimes. Effects on fish are determined not only by the temperature, but by the duration of exposure. Even if a reach is characterized by temperature that exceeds state criteria, if fish can avoid long exposure by migration or escape to refugia, consequences to growth and survival may be ameliorated. In many cases temperature can be useful as a surrogate measurement for identifying other degraded habitat factors.

Each of the assessment protocols and subsequent analyses that were applied to WRIA 17 streams were developed to meet different objectives, and have advantages and disadvantages (Table 5-4). The TFW protocol is particularly useful in describing baseline instream and habitat conditions. However, it does not address factors that change watershed-scale processes, such as road construction, water withdrawals, and timber harvest. It does not describe historic habitat conditions, or specifically describe restoration opportunities. The TFW assessment links riparian zone quality to in-stream habitat. TFW data is keyed to reference points that will facilitate monitoring of recovery or deterioration. The Big Quilcene Watershed Analysis does not include many key aspects of the WA protocol, such as a quantitative evaluation of pool area or substrate composition. The Watershed Analysis reports LWD presence as pieces per mile, a less rigorous value than the TFW measurement of key piece frequency. The Salmon Snow Watershed Analysis was based largely on aerial photograph analysis, which is generally inferior to field assessment. However, Watershed Analysis provides a more in-depth, multi-disciplinary examination that links habitat quality with geology and hydrology, and better describes the processes that have caused habitat degradation or may bring about recovery.

Table 5-4. Evaluation of Habitat Assessment Methods on a Simple Numerical Scale (1 – poor, 2 – fair, 3 – adequate)

Objective	TFW	EDT	Watershed Analysis	Bahls and Rubin
Provides baseline for monitoring	3	1	2	3
Identifies key limiting factors	2	3	2	3
Evaluates watershed processes	1	1	3	2
Compares historic to current conditions	1	3	2	3
Identifies protection and restoration	1	2	2	2

Quantified substrate composition and scour measurements are lacking from assessments of most WRIA 17 streams. In streams where high sediment load is currently limiting egg survival, or where substrate quality is expected to improve or deteriorate in the near future, quantified composition monitoring should be implemented in key index reaches. The complete TFW protocol (Schuett-Hames et al. 1996) is time consuming and expensive, but likely represents the best method to monitor change accurately. The EDT method uses data gathered under the TFW protocol, and can incorporate other less quantified assessments, to link habitat quality to fish production. The data included in this assessment focused on coho salmon production. Its reliance on non-quantified assessments in locations where quantified protocols have not been utilized has been criticized. Its authors defend this practice, stating that limiting factors will be accurately identified to guide recovery and conservation initiatives.

Bahls and Rubin (1996) completed the only comprehensive and standardized assessments of habitat in Chimacum Creek. They collected comprehensive baseline field data for long-term monitoring, and quantitatively assessed habitat loss. They identified fundamental watershed processes that were affected by development, and specific limiting factors affecting coho salmon production. Restoration opportunities were specifically identified in different parts of the watershed. Their assessment did not examine the effects of surface water or groundwater withdrawal on base stream flow.

Habitat assessment data can provide guidance as to where critical habitat persists or is dysfunctional, and where restoration efforts might be directed. A complex planning process must ensue to formulate a habitat recovery plan, that will likely prioritize actions that benefit certain sub-basins, and perhaps species. This plan must include a vision of the objectives of recovery. It is certain that all degraded habitat will not be restored, and that restoration will take at least decades to manifest effects on local fish populations. The outcome (success) of habitat restoration cannot be accurately foreseen. If conservation activities succeed in protecting the existing functional habitat, the viability of at-risk species is not assured. Nobody can say how much additional habitat will need to be restored in order to reverse the existing negative trends seen in many of the WRIA 17 stocks. Adaptive management is frequently cited as a valid approach to this uncertainty.

5.7 SUMMARY OF HABITAT QUALITY

The habitat assessment surveys summarized in this report concur in their conclusion that, throughout WRIA 17, freshwater and riparian habitat is in poor condition (Tables 5-5 through 5-12). Several common factors contribute to this conclusion. Spawning habitat quality is compromised by high sediment loading, and in many sub-basins is further affected by unstable channel substrate at high flow. In the lower reaches of streams where summer and fall chum salmon spawn, the banks have been modified in the interest of flood control, and channel complexity reduced to speed runoff. These modifications contribute to substrate instability and scour at high flow. All streams in WRIA 17 are characterized by low summer flow. Water diversions and disruption of wetlands which would otherwise buffer base flows, have potential to exacerbate low flows and their effects on rearing juvenile salmonids and spawning summer chum salmon. In all streams rearing habitat quality has been reduced because pool-forming LWD has been removed or is no longer being recruited from the riparian zone. Development of streamside land for agriculture and residential purposes, and timber harvest, has left many reaches without mature coniferous trees that generate stable LWD. Cleared areas are usually repopulated naturally with deciduous species, such as red alder, which can contribute to instream LWD, but they tend to decay more quickly and be less stable. Pool frequency and size is further reduced by high sediment loading. In some cases stream channels have been straightened, and side channels and meanders eliminated where, previously, deep, low-velocity pools would have provided suitable rearing habitat. Off channel wetland and beaver ponds, though they still exist in some streams, have been substantially reduced in developed stream corridors, with suitable over-winter rearing habitat reduced as a

result. Improperly constructed road culverts partially or completely block access to substantial areas of rearing, and in some cases spawning, habitat.

Table 5-5. Summary of Sub-Estuarine Habitat Quality for Streams in WRIA 17 (from Ames et al. 2000)

Stream or River	Estuarine Habitat Quality
Big Quilcene River	River mouth extended 1700 ft. by aggradation, channelization; 26% of original delta filled or obstructed by dikes.
Little Quilcene River	Dikes isolate mouth from distributary sloughs – 25% of original delta isolated
Thorndyke Creek	Nearly pristine
Chimacum Creek	Estuary relatively intact, no dikes, jetties, roads.
Salmon / Snow Creeks	Dysfunctional tidal channel due to relocation of Snow Cr; 25% of delta isolated from tidal flow by roads, causeways, railroad grade
Jimmycomelately Creek	5% of original delta isolated by roads or residential development. Stream mouth aggraded, perched above intertidal; log storage area affects benthic productivity

Sub-estuaries, those zones at the interface of the stream mouths and the primary estuaries of Hood Canal and the Strait of Juan de Fuca, have also been degraded (Table 5-5). They are critical habitat for summer and fall chum salmon that originate in WRIA 17 streams, as well as juvenile chum salmon and chinook salmon that migrate through these highly productive zones. Diking and filling of deltas has reduced the complex web of distributary channels and sloughs that support post-emergent chum salmon fry. During their early marine existence, chum salmon must adapt to the salt water, and find productive shallow water that provides abundant food and cover from predators.

Table 5-6. Summary of Fish Habitat Assessment Data by Sub-Basin

Sub-basin	Stream or River	Reach Assessed	Primary Data Source	Habitat Quality
Big Quilcene	Big Quilcene MS	0.0 – 3.3	Bernthal et al. (1999) BQWAT (1994)	Chum salmon spawning habitat poor – sediment load, channel instability, low flow Coho salmon rearing habitat fair to poor –
	Penny Creek	0.0 – 7.5	BQWAT (1994)	Inaccessible; potentially good coho salmon rearing habitat
	Townsend Creek	0.0 – 4.8	BQWAT (1994)	LWD low; fair cutthroat habitat
	Spencer Creek	0.0 – 2.5	BQWAT (1994)	Spawning habitat poor – high sediment load Rearing habitat poor – LWD low, pools small and infrequent
	Marple Creek		BQWAT (1994)	Spawning habitat degraded by sediment load Rearing poor – low LWD, pools inadequate
Little Quilcene	Little Quilcene MS	0.0 – 5.2	Bernthal et al. (1999)	Spawning habitat poor – low flow, sediment load high, channel unstable Rearing habitat poor – low LWD, low channel complexity, few pools
	Howe Creek	0.0 – 2.8	Bernthal et al. (1999)	Spawning habitat limited. Upper reaches dewatered in summer Rearing habitat fair – low LWD, wetlands provide winter habitat
	Ripley Creek	0.0 – 0.7	Bernthal et al. (1999)	Spawning habitat fair Rearing habitat fair – pools, LWD adequate
	Leland Creek	To lake	PEI and Leland Watershed Community (2000)	Low flow limits access; riparian zone degraded
	Donovan Creek Trib 17.0116 Trib 17.0018	– 1.9 – 1.0 0.0 – 1.8	PNPTC unpub data	Spawning habitat poor – sediment load, high winter flow Rearing habitat fair – riparian degraded, LWD low, channel unstable
Dabob Thorndyke	Tarboo Creek Trib 17.0130	– 7.0 0.0 – 1.1	PNPTC unpub data	Spawning and rearing habitat poor – high sediment load, channel aggraded, low LWD and pool quality.
	Thorndyke Trib 17.0171 Trib 17.0174	– 6.6 0.0 – 1.2 0.0 – 0.8	PNPTC unpub data	Spawning and rearing habitat poor – high sediment load from upstream logging, low summer flow
Ludlow	Shine Creek	0.0 – 3.0	PNPTC unpub data	Spawning habitat poor in lower reach – high sediment load. Rearing habitat in upper reach degraded, channelized; wetland offer winter rearing potential
Chimacum	Chimacum Creek mainstem, East Fork West Fork	Mainstem, East and West Forks	Bahls and Rubin (1996)	Spawning and rearing habitat poor – high sediment load, low channel complexity, LWD absent in valley reach, water quality marginal, low summer flow.
Salmon Snow	Snow Creek Salmon Creek	All 0.2 – 3.8	SSWAT (1996) Bernthal et al. (1999)	Spawning and rearing habitat poor – high sediment load, poor LWD recruitment potential, few pools, low summer flow, high winter flow.
West Sequim Bay	Jimmycomelately	0.0 – 1.5	McHenry et al. (1996)	Spawning and rearing habitat poor – high sediment load, channel simplified and aggraded.

Table 5-7. Factors for Decline of Summer Chum Salmon in WRIA 17 Streams of Hood Canal and the Eastern Strait of Juan De Fuca (from Ames et al. 2000)

	Rating of Effect of Habitat Factors On Life Stages					
	Low Flow or Peak Flow	**Channel Complexity and Floodplain Loss**	**Sediment Aggradation**	**Riparian Zone Degradation**	**Water Quality**	**Sub-Estuarine Habitat Loss**
Waterbody	**Spawning**	**Spawning and Incubation**	**Spawning and Incubation**	**Spawning and Incubation**	**Spawning and Incubation**	**Juvenile Rearing and Migration**
Big Quilcene River	High	High	High	Moderate		High
Little Quilcene River	High	High	Moderate	High		High
Chimacum Creek	High flow - moderate; Low flow – moderate/ low		High	Low	Low	Moderate
Snow Creek		High	High	High		High
Salmon Creek	Peak flow – High	High	Moderate	High		High
Jimmycomelately Creek		High	High	High		High

Table 5-8. Rating of the Effect of Habitat Degradation Factors on Coho Salmon Productivity in WRIA 17 Streams (PNPTC Unpublished Data 1997) and Salmonids in General (Bernthal et al. 1999)

	Habitat Degradation Factor and Lifestage Affected				
	Low Flow or Peak Flow	**Channel Modification and Floodplain Loss**	**Sediment Load and Aggradation**	**LWD Frequency and Recruitment Potential**	**Riparian Zone Degradation**
Stream	**Spawning and Rearing**	**Spawning and Rearing**	**Spawning, Incubation, And Rearing**	**Spawning and Rearing**	**Spawning and Rearing**
Big Quilcene River	Moderate	High	High	High	High
Little Quilcene River		Moderate	Moderate	High	High
Howe Creek		Low			Moderate
Ripley Creek		Moderate			Low
Donovan Creek and tribs	Moderate	Moderate	Moderate		
Tarboo Creek and tribs	Moderate	Low	Low		Moderate
Thorndyke Creek	Moderate	Low	Low		
Shine Creek	Moderate	Low	Low		
Chimacum Creek	High	High	High		High
Snow Creek	High	High		High	High
Salmon Creek	High	High		High	High
Jimmycomelately Cr.	High	High	High	High	High

Table 5-9. Tree Diameter (DBH) Distribution in the Riparian Zone of Summer Chum Salmon-Bearing Streams in WRIA 17 (from Ames et al. 2000)

Stream	Small (< 12”)	Medium (12 – 20”)	Large (> 20”)	No Buffer	Rating
Big Quilcene	44%	48%	0%	8%	2.5
Little Quilcene	79%	27%	0%	3%	2.7
Chimacum	42%	42%	0%	16%	2.6
Snow	50%	44%	0%	6%	2.6
Salmon	15%	63%	0%	22%	2.4
Jimmycomelately	34%	66%	0%	0%	2.3

Table 5-10. Riparian Forest Species Composition for Summer Chum Salmon-Bearing Streams in WRIA 17 (from Ames et al. 2000)

Stream	Mixed	Conifer	Deciduous	Shrub/grass	None	Rating
Big Quilcene	11%	40%	41%	5%	3%	2.1
Little Quilcene	42%	7%	48%	0%	3%	2.5
Chimacum	57%	0%	27%	16%	0%	2.4
Snow	14%	0%	80%	6%	0%	2.9
Salmon	63%	0%	15%	22%	0%	2.4
Jimmycomelately	15%	43%	42%	0%	0%	2.0

Table 5-11. Riparian Forest Buffer Width for Summer Chum Salmon-Bearing Streams in WRIA 17 (from Ames et al. 2000)

Stream	> 132 Feet Low Impact	66 – 132 Feet (Moderate Impact)	< 66 Feet (High Impact)	Rating
Big Quilcene	53%	2%	45%	1.9
Little Quilcene	3%	38%	60%	2.6
Chimacum	33%	26%	41%	2.1
Snow	17%	7%	76%	2.6
Salmon	8%	22%	70%	2.6
Jimmycomelately	0%	31%	69	2.7

Table 5-12. Summary of Habitat Data Collected from Salmon Creek, the Little Quilcene River, and the Big Quilcene River in 1992 (from Bernthal et al. 1999)

Stream	Percent Pool / Riffle/ Cascade	Percent Primary Secondary and Side Channels	Pool Depth <05/05-1.0/ >1.0 m	Pool Frequency Channel Width/Pool	Dominant Pool Forming Factors	LWD Volume m^3/100 m	LWD Frequency: Pieces per Channel Width	LWD Frequency: Key pieces per Channel Width	Log Jam Frequency per Channel Width
Salmon Creek									
2	39/42/19	96/4/0	64/34/2	4.6		7.5	0.32	0.03	0.04
3	36/6/58	90/2/1	88/8/4	1.8	Rocks boulders	44.6	1.02	0.19	0.15
5	36/47/17	97/2/1	86/13/1	4.6		8.8	0.44	0.10	0.00
Little Quilcene									
1	68/29/3	100/0/0	50/50/0	5.4	NA	0.4	0.14	0	0.00
2	37/12/51	97/3/0	46/44/0	4.1	NA	2.7	0.25	0.02	0.02
3	28/12/51	86/8/6	36/59/5	3.9	NA	4.1	0.22	0.04	0.04
4	23/19/57	95/4/1	37/53/10	4.8	NA	4.0	0.23	0.03	0.03
5	25/9/56	97/3/0	63/37/0	4.5	NA	2.7	0.15	0.03	0.06
Big Quilcene									
1	0/100/0	100/0/0	0/0/0	0.0		0.0	0.04	0.00	0.00
2	23/74/3	92/8/0	50/39/11	4.8		1.3	0.21	0.00	0.00
3	35/16/49	89/3/8	26/54/20	4.0		2.2	0.22	0.01	0.05
5	53/2/45	93/7/0	40/60/0	3.5		4.4	0.58	0.00	0.17
Howe Creek									
1	28/34/38	86/4/10	71/26/3	2.9	LWD	19.5	1.65	0.11	0.15
2	45/55/0	81/9/10	78/22/0	1.7	LWD	18.1	2.37	0.22	0.03
4	51/49/0	97/3/0	69/31/0	3.1	LWD	8.5	0.61	0.04	0.04
6	40/60/0	97/3/0	85/15/0	4.1	LWD, bank scour	9.6	0.34	0.05	0.01
7	27/29/45	91/10/1	95/5/0	5.5	LWD, rocks	3.3	0.21	0.03	0.04
Ripley Creek									
1	50/38/12	98/2/0	91/8/2	3.6	LWD	10.6	0.75	0.05	0.11

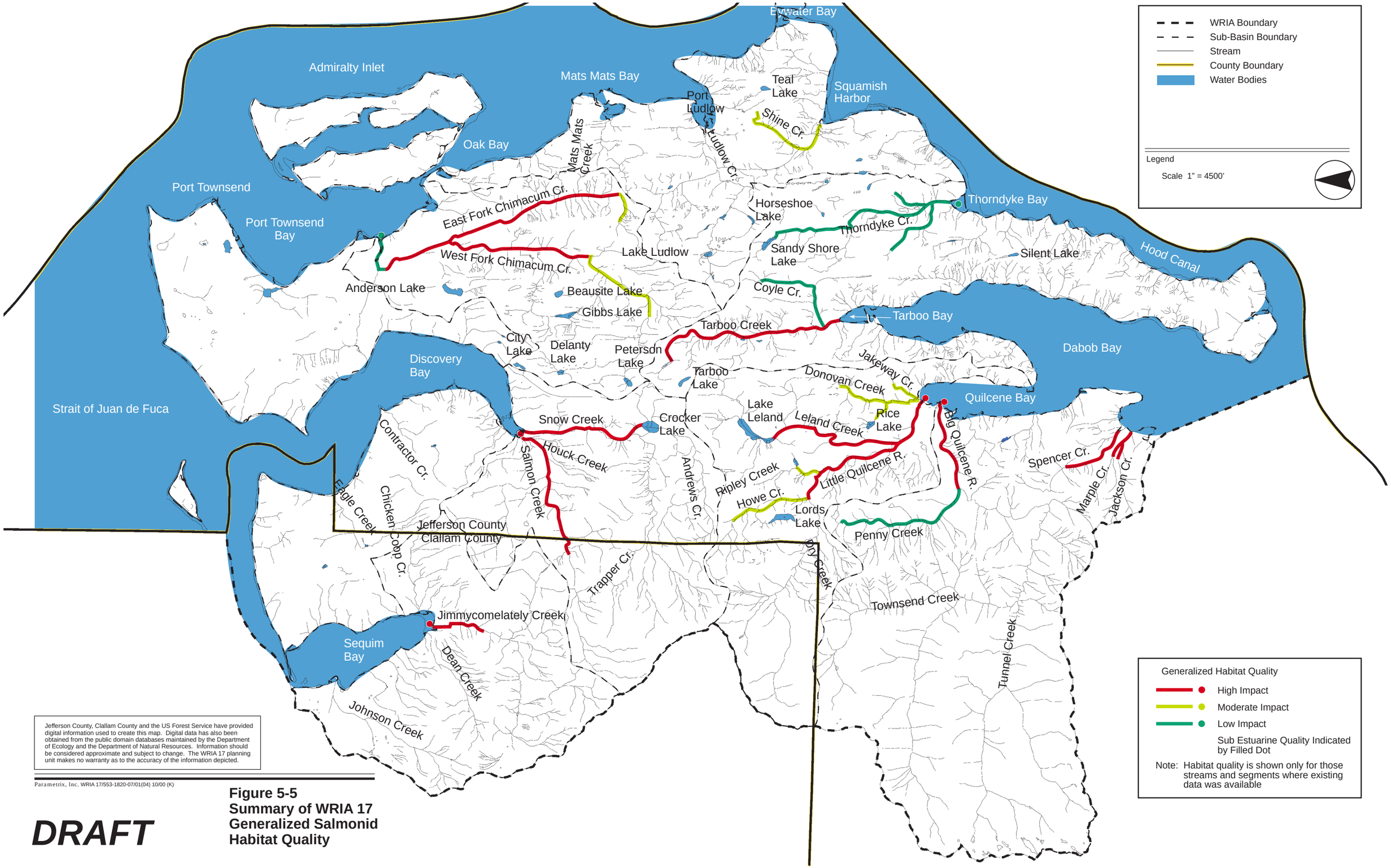
The overall quality of stream channel, riparian, and estuarine habitat in each drainage is mapped in Figure 5-5. Habitat quality is qualitatively described in terms of the extent to which it has been impacted by development or land use practices. The foregoing discussion in this chapter has summarized the variety of parameters that are measured by habitat assessment to characterize the state of the stream channel and riparian zone. The detailed nature of the habitat assessment data cannot be adequately represented on a two-dimensional graphic. The overall habitat impact ratings that are shown on Figure 5-5 were the result of a subjective summary of the habitat assessment data, expressed primarily in the context of effects on fish productivity. Because different streams were assessed using slightly different data collection protocols, and were designed to assess effects on different species and life stages of salmonids, a further level of subjectivity is introduced into a simplified and general characterization of habitat quality.

The rating of sub-estuarine quality are derived primarily from the assessment in the Summer Chum Salmon Recovery Initiative (Simenstad 2000 in Ames et al. 2000), and therefore focus on effects on the early marine life stage of chum salmon. Assessments of Donovan Creek, Tarboo Creek, Thorndyke Creek, and Shine Creek (PNPTC 1997) were focused on the freshwater life history stages of coho salmon, whereas assessments of the Big Quilcene River, Little Quilcene River, and Salmon Creek were not species specific.

The ratings mapped at this scale, furthermore, cannot express the full complexity of different levels of impact on different life history stages or species in different reaches. If one aspect of channel quality (e.g., sediment load) significantly reduces the survival of a single life stage (e.g. egg survival), the impact level in that stream is mapped as high. Generally speaking, aspects of degraded habitat in most drainages are not the result of a single or isolated factor. High sediment loading, for example, is a symptom of a degraded riparian zone, and/or channel instability, and/or channel modification throughout much of a drainage. The graphic will, then, allow quick reference to compare the overall health of stream habitats throughout WRIA 17, but the more detailed discussions of each sub-basin that follow afford a more detailed look at different reaches, and effects on different species and life stages.

5.8 INVENTORY OF BARRIERS TO FISH MIGRATION

A technical team comprised of state and tribal biologists and representatives of the Jefferson County Public Works Department and Conservation District, and Wild Olympic Salmon compiled a list of barriers to fish migration in WRIA 17 (Bahls 1997a) that were associated with County roads or property, with the intent of prioritizing them for repair. Prioritization factors included the amount of blocked habitat, quality of potential habitat, the status of affected fish stocks, and the cost of repair. The degree to which each species was affected by the barrier was rated. Benefits of barrier removal were assessed in terms of the potential value of restored fish production. A priority index was computed for each site as the fourth root of the following product of ratings:



Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.

Parametrix, Inc. WRIA 17/553-1820-07/01(04) 10/00 (K)

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Figure 5-5
Summary of WRIA 17 Generalized Salmonid Habitat Quality

[(Passability * Potential production) * (stock status * habitat quality * economic importance * cost)]

The results of this study and analysis are shown in Table 5-13. Restoring fish passage at the eleven sites identified in this study would involve one or more of the following corrective actions: culvert replacement, installation of upstream and downstream weirs to migration past gradient steps, and instream work to remove other barriers.

As yet there is no evaluation process in place to prioritize barrier removal, or habitat restoration, projects among the different sub-basins and streams in Hood Canal, the eastern Strait of Juan de Fuca, or WRIA 17 in particular. In part this is because it is not possible to accurately estimate the short- or long-term benefits of improving access to blocked habitat. The resource agencies are encouraging habitat restoration to proceed in all sub-basins, with the general goal of improving the productivity of all stocks of all species. Recovery plans for listed salmon ESU's, at this stage, seek to protect and restore all critical habitat.

Exhibit 18 shows the locations of barriers to fish passage, which were derived from two sources. Jefferson County supplied the 'Culverts 2000' data layer. From this dataset, only those culverts that are barriers to fish migration are mapped. The Department of Natural Resources Streamnet barriers locations were also imported. The maps also show natural and man-made partial and complete barriers to migration. Some of the culvert data is redundant to the Streamnet man-made barriers data. Differences between the two databases have not been reconciled.

Migration barriers continue to be evaluated in WRIA 17. The Salmon and Steelhead Habitat Inventory and Analysis Project (SSHIAP) is developing a database that will facilitate estimation of the benefits of restoring passage at various sites.

5.9 SUMMARY OF PROJECTED IMPACTS OF GROWTH AND HUMAN IMPACTS ON HABITAT

Population increase can potentially influence freshwater, riparian, and nearshore habitat quality through a number of pathways that affect aquatic ecosystem integrity and fish productivity. A fundamental impact pathway involves the increase in demand for water, which may involve increased withdrawal of groundwater, diversion of surface water, import of water from out of the local basin. The extent to which increased groundwater withdrawal may affect streamflow, particularly during the late summer and fall when streamflow is usually at critically low levels in WRIA 17 systems, is difficult to predict. The geomorphology underlying the aquifers of WRIA 17 sub-basins in discussed elsewhere in this assessment, and the factors described which control the connectivity between groundwater and surface flow. Development to meet increased residential use in rural areas will most likely utilize individual septic systems, which, if improperly sited or constructed, may increase nutrient and fecal coliform loading to the surface aquifer.

Most of the major salmonid-bearing stream basins in WRIA 17 have been moderately or highly impacted by land use practices or agricultural and residential development. Development patterns and land-use practices that began over 100 years ago have dramatically altered stream channels, cleared riparian forest and vegetation, and drained or disconnected side channels and wetlands. Development in the floodplains of large streams has necessitated construction of flood control measures, such as straightening channels, clearing them of LWD, construction of dikes, and armoring of banks. In several systems timber harvest

Table 5-13. Potential Habitat Gained by Removing Barrier to Fish Passage at Road Crossing Sites in Eastern Jefferson County (from Bahls 1997a)

Sub-Basin	Site	Species Present – Blockage Rating	Potential Habitat Restored	Priority Rating
Big Quilcene	Spencer Creek	Coho salmon – total barrier Steelhead – total barrier Fall Chum salmon – total barrier Cutthroat – total barrier	0.3 miles ; 28,500 square feet habitat quality poor for coho salmon, steelhead, cutthroat; good for chum salmon	15.32
	Indian Creek	Coho salmon – total barrier Steelhead – total barrier Fall Chum salmon – total barrier Cutthroat – total barrier	0.2 miles; 8,400 square feet habitat quality good for all species	14.71
Little Quilcene	Leland Creek tributary	Coho salmon – total barrier Steelhead – total barrier Cutthroat – total barrier	0.34 miles; 13,500 square feet habitat quality fair all species	9.22
	Donovan Creek tributary – Outlet from Rice Lake	Coho salmon – total barrier Steelhead – total barrier Cutthroat – total barrier	0.23 miles; 14,300 square feet habitat quality poor for all species	6.96
Dabob – Thorndyke	Tarboo Creek mainstem	Coho salmon – total barrier Steelhead – total barrier Cutthroat – 80% barrier	1.37 miles; 42,000 square feet habitat quality fair all species	10.64
	East Fork Tarboo Creek	Coho salmon – total barrier Steelhead – total barrier Cutthroat – total barrier	1.48 miles; 75,100 square feet habitat quality good all species	14.04
	East Branch East Fork Tarboo Cr	Coho salmon – total barrier Steelhead – total barrier Cutthroat – total barrier	0.73 miles; 39,300 square feet Habitat quality fair all species	12.57
	North Branch East Fork Tarboo Cr	Coho salmon – total barrier Steelhead – total barrier Cutthroat – total barrier	1.10 miles; 47,600 square feet Habitat quality fair all species	10.66
	Thorndyke Creek	Fall Chum salmon –20% barrier No barrier to coho salmon, steelhead, CT	7.18 miles; 504,900 square feet Habitat quality good all species	7.21
Ludlow	Little Goose Creek	Coho salmon – 10% barrier Steelhead – not a barrier Cutthroat – 10% barrier	0.23 miles; 8,100 square feet Habitat quality poor all species	2.96
Chimacum	West Fork Chimacum Creek Barnhouse Creek	Coho salmon – total barrier Steelhead – total barrier Cutthroat – total barrier	0.36 miles; 15,200 square feet Habitat quality good all species	9.71

and road building in the upper basins, combined with channel simplification and riparian clearing, have increased sediment loading. Aggradation that results in the lower reaches of systems then exacerbates flood risk, which has prompted further flood control measures. In total, all these changes have dramatically reduced the productivity of fish populations in these systems.

As preserving and restoring the integrity of aquatic systems has attained higher priority in the last twenty years, the habitat requirements of fish, and fluvial and biological functions that create and maintain suitable habitat, are becoming better understood. Recovery of salmon populations requires that existing high quality habitat be maintained and protected, and that degraded habitat be allowed to recover. Development patterns and land-use practices in rural areas in WRIA 17 will influence the extent to which habitat recovery occurs. Protection of streamside riparian buffers will be important. Concentrated development will result in increase in impervious surface from which stormwater runoff must be detained, treated, and infiltrated in order to maintain water quality and prevent increasing peak streamflow. Removing or setting back dikes, particularly on those parcels near stream mouths, may contribute to long-term salmon recovery objectives. Potential impacts of growth and new development will also depend in part on protection of critical areas which currently contain high quality stream habitat or have high potential for restoration.

5.10 FISHERIES MANAGEMENT

This section describes the commercial and recreational fisheries that harvest summer chum salmon and coho salmon stocks from WRIA 17, and the objectives that the Tribes and the WDFW have established for planning annual fishing regimes. This discussion will not trace an exhaustive chronology of fishery management or regulatory actions, except to note where significant changes have occurred in response to conservation issues, such as the declining status of summer chum salmon and their listing under the Endangered Species Act. We will briefly describe the data and tools that are used in fisheries management, and the extent to which those data are adequate to managing local stocks and stock aggregates, such as those in WRIA 17. It is not the intent of this document to evaluate whether current harvest management policies reflect an equitable or effective allocated of conservation burden among the various factors that limit salmon productivity in this region.

5.11 CURRENT COMMERCIAL AND RECREATIONAL FISHERIES

Coho salmon that originate in Hood Canal are caught in commercial and recreational fisheries along the west coast of Vancouver Island and Washington, in the Strait of Juan de Fuca, and in Puget Sound. Their catch distribution is known from recoveries of coded-wire tagged smolts that are released from various hatchery and net pen facilities in Hood Canal. These index tag groups are released from the George Adams Hatchery on the Skokomish River, the QNFH, and from net pens in Quilcene Bay and Port Gamble. Wild coho salmon smolts are tagged at the WDFW research station on Big Beef Creek, just north of Seabeck on the east shore of Hood Canal. A coordinated, coast-wide, multi-agency effort is made to sample all salmon fisheries to recover these fish. The data is used to describe catch distribution and to estimate the fishery- and stock-specific exploitation rates, (i.e. the proportion of the unfished abundance of each stock which is caught in each fishing area). Fewer tag data are available to describe the harvest of coho salmon stocks that originate in the Strait of Juan de Fuca. Strait stocks in WRIA 17 are not tagged, so their harvest must be inferred from relatively small numbers of tagged coho salmon that are released from the Dungeness and Elwha hatcheries.

Along the outside coast of Washington, commercial troll and recreational (hook and line) fisheries directed at coho salmon currently occur from late July to early September. These fisheries are regulated

under catch quotas set by the Pacific Fisheries Management Council. In the Strait of Juan de Fuca, recreational coho salmon fisheries may occur in the same period. In the past, these Strait fisheries have been constrained by seasons and bag limits, but in recent years more areas have had specific catch quotas applied. Commercial fisheries directed at coho salmon have not occurred in the Strait since the late 1980's, with the exception of limited fishing in the Elwha River and Dungeness Bay which target hatchery production. However, substantial numbers of coho salmon are caught incidentally during annual net fisheries for sockeye and chum salmon. In the last ten years increasingly restrictive measures have been imposed on these fisheries to reduce the incidental coho salmon catch. For example, the sockeye fishery is terminated now in late August, prior to the peak of coho salmon migration, and the chum salmon fishery is delayed until mid-October, after the peak of coho salmon migration. Sockeye and chum salmon fisheries are conducted only by tribal commercial fishermen. Hood Canal coho salmon, and to a lesser extent, Strait coho salmon stocks, are also caught in commercial and recreational fisheries in central and northern Puget Sound. Directed commercial and recreational coho salmon fisheries occur in September and early October in central Puget Sound, where the season length and catch objectives are managed in-season to meet the harvest objectives of southern Puget Sound coho salmon stocks.

The WDFW is developing recreational fishing regimes that selectively harvest hatchery-origin coho salmon, and, in cooperation with tribal co-managers, is attempting to mark (with an adipose fin clip) the majority of coho salmon produced by hatcheries in Puget Sound and the Washington coast. The intent of this program is to reduce the harvest mortality of wild coho salmon stocks, while maintaining high quality fishing opportunity. A similar strategy is being pursued by fisheries managers in Oregon and British Columbia. Selective harvest of marked coho salmon that pass through a gauntlet of fisheries presents technical challenges to the integrity of the coded-wire tag sampling system and interpretation of the tag data. Tag data are widely used to estimate the harvest distribution and exploitation rates for wild and hatchery stocks – an essential function of responsible fisheries management. Nonetheless, selective coho salmon fisheries offer a viable solution for reducing the harvest of weak wild stocks, such as are found in the eastern Olympic Peninsula streams in WRIA 17, in mixed-stock fisheries on the Washington coast, and in the Strait of Juan de Fuca and Puget Sound.

Hood Canal fall chum salmon are caught primarily by commercial fisheries that occur in U.S. and Canadian waters in the Strait of Juan de Fuca. These fisheries target fall chum salmon stocks. In Washington, the tribes conduct a fishery in the Strait from mid-October into early November that is constrained by a catch ceiling that reflects the forecast overall abundance of fall chum salmon returning to Puget Sound. A significant number of Hood Canal fall chum salmon are also caught in central Puget Sound during Indian and non-Indian commercial fisheries that target southern Puget Sound stocks. Hood Canal chum salmon are also caught, to a lesser extent in fisheries in the northern Sound (i.e. San Juan Islands and Possession Sound).

Summer chum salmon are also intercepted by Canadian coho salmon fisheries that occur in the western Strait. Genetic analysis of samples collected from these fisheries have shown that Hood Canal stocks comprise up to 60 percent of the incidental chum salmon catch taken by this fishery, which occurs in September (Ames et al. 2000). Fall chum salmon fisheries in Washington, in the Strait and San Juan Islands have not been shown to intercept Hood Canal summer chum salmon. However, current analytical techniques may not be capable of resolving very small contributions of summer chum salmon.

"Terminal" recreational and commercial fisheries for coho salmon and fall chum salmon occur annually in Hood Canal. The tribes schedule a fishery inside Quilcene Bay and Dabob Bay specifically to harvest the early-timed coho salmon return to the QNFH and the Quilcene Bay pen facility. It generally occurs from the last week of August through September. Tribal fisheries on fall coho salmon are also scheduled in the main body of Hood Canal, and in Port Gamble, from mid-September through the middle of

October. Tribal and non-tribal commercial chum salmon fisheries, which are scheduled to target the large hatchery return, generally begin in the northern Canal in mid-October and may persist through the third week of November in the southern Canal. Tribal coho salmon and chum salmon fisheries also occur in the Skokomish River. Though commercial fishing for chinook salmon has been tightly constrained due to low abundance, it does occur when summer chum salmon are present in southern Hood Canal. Catch is currently monitored to determine whether summer chum salmon are being caught.

5.12 HARVEST OBJECTIVES

Coho salmon fisheries in Washington are co-managed by the tribes and WDFW to achieve a maximum sustainable exploitation rate on wild Hood Canal coho salmon, and sufficient escapement to hatcheries to perpetuate the enhancement programs. The state and tribes negotiate a fishing regime that will obtain this rate, and approach, to the extent possible, equal Indian and non-Indian sharing of the catch. A fisheries simulation model, which includes fisheries in British Columbia as well as those in Washington, is used to evaluate the impacts of proposed fishing quotas and season structure in each fishing area. Incidental catch in fisheries directed at other species, and non-landed mortality (encounters with sublegal fish, gear drop-out) are also accounted in the model. As previously mentioned, the coastal fishing regime is ultimately adopted by the Pacific Fisheries Management Council. Fisheries in the Strait of Juan de Fuca and Puget Sound are regulated by WDFW, and by each tribe that participates in each fishing area.

One of the many challenges faced by the Washington co-managers is that Canadian fisheries have, in the past, exerted 50 percent or more of the total harvest on most Washington stocks. In years of low abundance, this has left little surplus production after Canadian harvest occurred, and has forced most of the conservation burden onto Washington fisheries. However, in the late 1990's, Canadian coho salmon stocks were also severely depressed, and formerly large-scale commercial and recreational fisheries, such as those that occurred off the north and west coast of Vancouver Island, were severely constrained or closed. With low marine survival affecting all stocks, Washington fisheries have continued to be limited in order to conserve wild coho salmon for escapement.

The maximum sustainable harvest rate for wild Hood Canal coho salmon is based on a stock-recruit relationship that is derived from spawner abundance and smolt production observed at Big Beef Creek. Smolt production varies according to the complex of factors that affect freshwater survival, from spawning until the smolts emigrate to salt water. Variable marine survival, up to the time coho salmon recruit to the fisheries, has played a significant role in determining the abundance of returning adults. The stock-recruit relationship predicts smolt abundance under average freshwater survival conditions. Fishery managers, knowing the conditions that affected outmigrating smolts, must then examine recent trends in marine survival to forecast the abundance of returning adults. Under normal conditions of freshwater and marine survival managers attempt to limit total fishing mortality to about 60 percent to maintain current populations. A lower exploitation rate objective may be set if poor freshwater and/or marine survival is thought to limit the return or increase populations.

Coho salmon fisheries in Hood Canal are currently constrained to minimize the incidental harvest of summer chum salmon. Fishing in the main body of the Canal is delayed past the third week of September, to allow most summer chum salmon to enter freshwater. Fishing in Quilcene and Dabob Bay is restricted to beach seine gear, which allows incidentally caught summer chum salmon to be released. If summer chum salmon escapement surveys suggest that escapement goals will be achieved, gillnet fisheries may be implemented on a very time-and area-limited scale. The Summer Chum Salmon Recovery Plan (Ames et al. 2000) includes an in-depth analysis of historical incidental harvest of summer chum salmon in Hood Canal coho salmon fisheries. Since the listing of summer chum salmon, the annual fishing regime must

meet the National Marine Fisheries Service standard for not jeopardizing the likelihood of recovery of summer chum salmon. Monitoring of the coho salmon fishery in the past five years has confirmed that very few chum salmon are caught during the coho salmon fishery in the central body of Hood Canal, and the majority of those are fall chum salmon.

Coho salmon fisheries in Washington have been managed based on the forecast abundance of wild stocks returning to the various regions of Puget Sound – South Sound, Hood Canal, the Stillaguamish/Snohomish , and Skagit basins. If the abundance of any one of these "primary" stock aggregates was forecast to be low, all intercepting fisheries would be constrained to optimize spawning escapement. However, coho salmon from the Strait of Juan de Fuca region were not managed as a primary stock until the late 1990's, which means that fisheries conservation measures were not considered, except in the terminal and extreme terminal areas. In part this was due to the lack of adequate data to accurately estimate either spawning escapement or productivity, or derive appropriate harvest objectives. Since 1997, conservation measures have been implemented to reduce the harvest of Strait coho salmon.

Fisheries directed at fall chum salmon in Hood Canal occur from mid-October through the third week of November. They are managed to exert a high terminal harvest rate on hatchery-origin fall chum salmon, which return somewhat earlier than wild fall chum salmon. Both Indian and non-Indian fleets participate. The hatchery return has frequently been 500,000 to one million fish. Given the freshwater entry timing of summer chum salmon stocks in Hood Canal, they are not caught in the fall chum salmon fishery. Because chum salmon production in Southeast Alaska and British Columbia has been consistently high in recent years, the value of fall chum salmon has declined. Fishing effort and harvest have declined significantly as a result, with much of the value of the catch, particular of those dark chum salmon caught late in the season, stemming from sale of roe. Though fishermen have attempted to develop alternative markets for chum salmon, local concern has arisen over what is perceived to be wastage of chum salmon carcasses.

Recreational fisheries in Hood Canal are also constrained to minimize encounters and incidental catch of summer chum salmon. Coho salmon fisheries attract considerable effort during September, particularly in Quilcene Bay, when summer chum salmon are still present, but gear specific to coho salmon does not generally hook chum salmon. The increasingly popular fall chum salmon fishery occurs in the vicinity of the Hoodsport Hatchery in November, long after summer chum salmon have entered freshwater and spawned.

Escapement and runsize criteria have been developed for all summer chum salmon stocks, such that when abundance is predicted to approach these thresholds, management actions can be planned to reduce incidental harvest. The critical escapement threshold for the Snow/Salmon and Big Quilcene/Little Quilcene stocks has been calculated to be 800. For the Jimmycomelately stocks the escapement threshold is 200.

6. INSTREAM FLOW

6.1 INTRODUCTION

Many streams within WRIA 17 have theoretically optimum instream flow hydrologies developed by one or more investigators. Optimum flow hydrologies were developed using one of two commonly accepted methods: The toe-width method and the Instream Flow Incremental Method (IFIM). These methods are those recommended by Washington State resource agencies to develop theoretical optimum instream flow hydrologies.

This section summarizes existing theoretically optimum instream flow predictions for WRIA 17, and describes the current administrative status of instream flows. Information is also available from recent toe-width studies, and an IFIM study, to develop optimum instream flows for other streams. Fish species considered included chum salmon, coho salmon, and chinook salmon and steelhead trout; lifestage requirements considered included spawning and juvenile rearing. Taken together, there is enough information to develop optimum instream flows for most of the larger streams in the WRIA.

No streams within the WRIA have instream flows set by the Department of Ecology (Ecology) as administrative rules. The Port Townsend municipal diversion is, however, managed to comply with a voluntary instream flow arrangement, which restricts diversion during low-flow periods.

6.1.1 Instream Flows and Current Administrative Status

The Department of Ecology, under the Water Resources Management Program (WAC 173-500) is authorized, among other things, to "...establish flows on perennial streams of the state in amounts necessary to provide for preservation of wildlife, fish, scenic, aesthetic, and other environmental values, and navigational values..."; and "...set forth streams closed to further appropriation" (Ecology 2000b). Optimum instream flows become instream flows when they are adopted as administrative rules. The seniority of instream flow rules with respect to water right is the date of their adoption; they do not supercede senior water rights but rather condition those junior. No instream flow rules have been developed for WRIA 17 (Davidson 2000 personal communication).

An insteam flow only applies to new, future water rights and does not require anyone to put any water in the stream for fish. The instream flow is the flow level that exceeds what is needed to preserve and protect fish and other environmental values. All the flow greater than the instream flow can be allocated out of the stream by Ecology issuing new water rights. The instream flow is not a minimum level that must be reached or restored, it is merely the flow level that allows new water rights to be approved.

A stream may be dry in August due to existing legal diversions that remove all the water from the stream. An instream flow set by a new rule on that stream would not require anyone to put water back in the stream. The instream flow in the new rule would merely be stating under what condition Ecology would issue new water rights. Ecology has no authority under state law to require any existing, legal, water diverter to restore flow into the stream, even if all fish and other instream environmental values are eliminated by the diversion (Ecology).

6.1.2 Definitions

"Instream flows" is a term that is often used loosely. This report will refer to "instream flow study results" where field data and modeling have resulted in a series of theoretically optimum flow

hydrologies, or flow/habitat predictions that have not yet been used to develop optimal instream flows. "Optimum instream flows" refers to situations where responsible parties have analyzed the predictions and developed a series of optimal flows, generally by month or by season. "Instream flows" refers to flow recommendations that have been adopted into state rules. Even then, that instream flow will not be a flow that can be necessarily observed in the stream under current conditions, or that was observed under historic conditions. In the water right hierarchy, the date of the instream flows' adoption into the rule is its seniority. Thus, only water rights issued after the date of the instream flow rule's adoption are subject to the restrictions of the instream flow. Because of this, in many basins with senior water rights, a junior instream flow may not be observed often, or during all seasons.

It is important to note that while instream flow study results are based on data collected in the field, they are not data themselves. They are estimates of optimum flow hydrologies required to provide habitat for specific species and lifestages. They are based on data collected in the field and on descriptions of fish habitat requirements, and should be seen as results of a predictive model. (Predictive models have the strengths and weaknesses of their assumptions and their methods. Much of the debate around instream flow methods is debate about assumptions, and about most appropriate analysis methods.)

In particular, it is important to review predictive model results against estimates of hydrologic conditions. This allows the investigator to see where model predictions lie with respect to historical or current flow regimes. This comparison is presented in section 5 of this report.

6.2 OPTIMUM INSTREAM FLOWS AND STUDY RESULTS

There are a series of instream flow investigations for many streams in WRIA 17 that have been made by Washington Departments of Ecology and Fish and Wildlife (Ecology and WDFW 1997, 1999), as well as a recently completed study on the Big Quilcene River (Caldwell 1999).

Two methods of generating optimum instream flow hydrologies have been used. The first is the "toe-width" method (Swift 1976, 1979). The toe-width method relies on physical measurements of stream width, generally in spawning reaches, and generates a single theoretical optimum instream flow value for each life stage considered. These are then used to develop theoretical optimum instream flow hydrologies. It is often used because it is relatively inexpensive in terms of investigator time, and allows a larger number of streams to be investigated for a given amount of staff resources (Morhart 1986). Table 6-1 summarizes toe-width study results, and resulting theoretical optimum instream flow hydrologies, where available, developed by Ecology and WDFW (Ecology and WDFW 1997, 1999).

The Instream Flow Incremental Method (IFIM) (Bovee et al. 1998) was used by Ecology to generate a series of predicted habitat values (Weighted Usable Area, or WUA) at a series of different flows for a series of salmonid species and life stages for the Big Quilcene River (Caldwell 1999). Washington Departments of Ecology and Fish and Wildlife recommend the IFIM method for generating theoretical optimum instream flow hydrologies in Washington. The IFIM method is more costly in terms of staff resources than some other methods. However, because it generates a series of habitat/flow predictions for various species and lifestages, it is a much more flexible tool for resource managers in evaluations of various flow regimes (Morhart 1986). Habitat predictions (WUA vs. flow) for the Big Quilcene River are presented in Table 6-2.

Previous investigations using the toe-width method have also resulted in theoretical optimum instream flow hydrologies for streams in WRIA 17 (Hiss 1993; Beecher 1980a). These theoretical optimum instream flow hydrologies are summarized in Table 6-3. The Departments of Ecology and Fish and

Table 6-1. Summary of Theoretical Optimum Instream Flow Hydrologies Presented by Ecology and WDFW, using the Toe-Width Method (Ecology and WDFW 1997, 1999)

Stream[a]	Stream Number[b]	Months	Theoretical Optimum Flow (cfs)	Species/Lifestage	Source	Sub-basin
Chicken Coop Creek	17.0278	All	3	Steelhead rearing	Ecology and WDFW (1997)	West Sequim Bay
Chimacum Creek	17.0203		51.7	Chinook salmon spawning	Ecology and WDFW (1999)	Chimacum
			25.7	Coho salmon spawning		
			51.7	Chum salmon spawning		
			46.6	Steelhead spawning		
			10.6	Steelhead rearing		
			9.5	Salmon rearing		
Dean Creek	17.0293	Nov-Jan	11	Coho salmon spawning	Ecology and WDFW (1997)	West Sequim Bay
		Feb-Apr	7			
				Steelhead rearing		
		May-Oct	4			
Donovan Creek	17.0115		32.1	Chinook salmon spawning	Ecology and WDFW (1999)	Little Quilcene
			15.5	Coho salmon spawning		
			32.1	Chum salmon spawning		
			29.8	Steelhead spawning		
			6.1	Steelhead rearing		
			5.5	Salmon rearing		
Howe Creek	17.0090		35.2	Chinook salmon spawning	Ecology and WDFW (1999)	Little Quilcene
			17.1	Coho salmon spawning		
			35.2	Chum salmon spawning		
			32.6	Steelhead spawning		
			6.8	Steelhead rearing		
			6.1	Salmon rearing		
Jimmycomelately Creek	17.0285	Sep-Jan	24	Coho, chum salmon spawning	Ecology and WDFW (1997)	West Sequim Bay
		Mar-Apr	44	Steelhead spawning		
		May-Jun	30	Juvenile rearing, incubation		
		Jul-Aug	10	Steelhead rearing		

Table 6-1. Summary of Theoretical Optimum Instream Flow Hydrologies Presented by Ecology and WDFW, using the Toe-Width Method (continued)

Stream[a]	Stream Number[b]	Months	Theoretical Optimum Flow (cfs)	Species/Lifestage	Source	Sub-basin
Johnson Creek	17.0301	Nov-Jan	13	Coho salmon and chum salmon spawning	Ecology and WDFW (1997)	West Sequim Bay
		Feb	8			
		Mar-Apr	26	Steelhead spawning		
		May-Jun	17	rearing, incubation		
		Jul-Oct	5	Steelhead rearing		
Leland Creek	17.0077		65.7	Chinook salmon spawning	Ecology and WDFW (1999)	Little Quilcene
			33.1	Coho salmon spawning		
			65.7	Chum salmon spawning		
			58.3	Steelhead spawning		
			13.9	Steelhead rearing		
			12.5	Salmon rearing		
Little Quilcene River	17.0076		117.7	Chinook salmon spawning	Ecology and WDFW (1999)	Little Quilcene
			61.2	Coho salmon spawning		
			117.7	Chum salmon spawning		
			100.6	Steelhead spawning		
			27.1	Steelhead rearing		
			24.7	Salmon rearing		
Ludlow Creek	17.0192		63.9	Chinook salmon spawning	Ecology and WDFW (1999)	Ludlow
			32.1	Coho salmon spawning		
			63.9	Chum salmon spawning		
			56.8	Steelhead spawning		
			13.5	Steelhead rearing		
			12.1	Salmon rearing		
Marple Creek	17.001		Dry		Ecology and WDFW (1999)	Big Quilcene
Ripley Creek	17.0089		Dry		Ecology and WDFW (1999)	Little Quilcene
Spencer Creek	17.0004		27.8	Chinook salmon spawning	Ecology and WDFW (1999)	Big Quilcene
			13.3	Coho salmon spawning		

Table 6-1. Summary of Theoretical Optimum Instream Flow Hydrologies Presented by Ecology and WDFW, using the Toe-Width Method (continued)

Stream[a]	Stream Number[b]	Months	Theoretical Optimum Flow (cfs)	Species/Lifestage	Source	Sub-basin
			27.8	Chum salmon spawning		
			26.1	Steelhead spawning		
			5.2	Steelhead rearing		
Spencer Creek (con't)			4.6	Salmon rearing		
Tarboo Creek	17.0129		40.4	Chinook salmon spawning	Ecology and WDFW (1999)	Thorndyke
			19.8	Coho salmon spawning		
			40.4	Chum salmon spawning		
			37.0	Steelhead spawning		
			8	Steelhead rearing		
			7.1	Salmon rearing		
Thorndyke Creek	17.0170		49.7	Chinook salmon spawning	Ecology and WDFW (1999)	Thorndyke
			24.6	Coho salmon spawning		
			49.7	Chum salmon spawning		
			44.9	Steelhead spawning		
			10.1	Steelhead rearing		
			9.1	Salmon rearing		
Unnamed Mats Mats Bay tributary	17.0200		12.5	Chinook salmon spawning	Ecology and WDFW (1999)	Ludlow
			5.8	Coho salmon spawning		
			12.5	Chum salmon spawning		
			12.4	Steelhead spawning		
			2.1	Steelhead rearing		
			1.8	Salmon rearing		

[a] Streams are presented alphabetically for ease of reference.

[b] Stream numbers are from Williams et. al. (1975).

Note: Information presented in the 1999 report are results of toe-width calculations only, which would be used to develop a recommended flow regime. Information presented in the 1997 report for West Sequim Bay tributaries, has been developed into recommended flow regimes.

Table 6-2. Instream Flow Incremental Method (IFIM) study results for the Big Quilcene River

Lifestage	"Optimum Flow" (Highest Predicted WUA) (cfs)	Comments
Coho salmon spawning	90	Caldwell (1999) notes correctly that "Determining a minimum instream flow...requires more than choosing the peak WUA flow for one lifestage of one species...Setting a minimum instream flow...require considering long-range management plans as determined by the state and federal...agencies and affected Tribes. ..reaching a conclusion about an appropriate minimum instream flow involves integrating the results of the IFIM study with consideration of...additional variables..." such as incubation needs, in- and out-migration flows, water quality, sediment load and water temperature.
Chinook salmon spawning	120	
Chum salmon spawning	180	
Steelhead spawning	190	
Steelhead juvenile	40	
Chinook juvenile salmon	60	

Note: Habitat predictions of "optimum flow" for various species and life stages in the Big Quilcene River (Caldwell 1999) is predicted as "Weighted Usable Area" (WUA), an index of amount of habitat predicted to be present at a given flow.

Table 6-3. Summary of Thoretical Instream Flow Predictions in WRIA 17 Presented by U.S. Fish and Wildlife Service (Hiss 1993)

Stream[a]	Stream Number[b]	Months	Theoretical Optimum Flow (cfs)	Species/lifestage	Source	Sub-basin
Big Quilcene River	17.0012	Sep-Jan	198	Chinook salmon and chum salmon spawning	Data from Beecher (1980a) applied to model of Swift (1979)	Big Quilcene
		Feb-Jun	165	Steelhead spawning	Beecher (1980a)	
		Jul-Aug	50	Steelhead rearing		
Chevy Chase Creek	17. 0215	Stream intermittent; no suitable measurement sites			Hiss (1993)	Quimper
Chicken Coop Creek	17.0278	Oct-Jan	4	Coho salmon spawning	Hiss (1993)	
		Feb-Sep	3	Coho salmon rearing		
Mainstem Chimacum Creek	17.0203	Nov-Jan	58	Chum salmon spawning	Data from Beecher (1980a) applied to model of Swift (1979)	Chimacum
		Feb-Jun	50	Steelhead spawning	Beecher (1980a)	
		Jul-Oct	12	Steelhead rearing		
East Fork Chimacum Creek	17.0205	No suitable measurement sites			Hiss (1993)	Chimacum
West Fork Chimacum Creek	17.0203	Nov-Jan	8	Coho salmon spawning		Chimacum
		Feb-Jun	17	Steelhead spawning		
		Jul-Oct	3	Steelhead rearing		
Contractors Creek	17.0270	Oct-Jan	4	Coho salmon spawning	Hiss(1993)	Miller
		Feb-May	8	Steelhead spawning		
		Jun-Sep	1	Steelhead rearing		
Donovan Creek	17.0115	Nov-Jan	35	Chum salmon spawning	Data from Beecher (1980a) applied to model of Swift (1979)	Little Quilcene
		Feb-Jun	30	Steelhead spawning	Beecher (1980a)	
		Jul-Oct.	7	Steelhead rearing		
Eagle Creek	17.0272	Stream intermittent, no suitable measurement sites or anadromous spawning reaches accessible by public road.			Hiss (1993)	Quimper
Howe Creek	17.0090	Nov-Jan	9	Coho salmon spawning		Little Quilcene
		Feb-Oct	3	Coho salmon rearing		
Jimmycomelately Creek	17.0285	Feb-Jun	30	Steelhead spawning	Beecher (1980b)	West Sequim Bay

Table 6-3. Summary of Theoretical Instream Flow Predictions in WRIA 17 Presented by U.S. Fish and Wildlife Service (Hiss 1993) (continued)

Stream[a]	Stream Number[b]	Months	Theoretical Optimum Flow (cfs)	Species/lifestage	Source	Sub-basin
		Jul-Aug	6	Steelhead rearing		
Johnson Creek	17.301	Oct	4	Coho salmon spawning	Hiss (1993)	West Sequim Bay
		Nov-Jan	10	Chum salmon spawning		
		Feb-Jun	10	Steelhead spawning		
		Jul-Aug	2	Steelhead rearing		
Leland Creek	17.0077	Nov-Jan	22	Coho salmon spawning	Hiss (1993)	Little Quilcene
		Feb-Jun	40	Steelhead spawning		
		Jul-Oct	9	Steelhead rearing		
Little Quilcene River	17.0076	Nov-Jan	85	Chum salmon spawning	Data from Beecher (1980a) applied to model of Swift (1979)	Little Quilcene
		Feb-Jun	75	Steelhead spawning	Beecher (1980a)	
		Jul-Oct	20	Steelhead rearing	Beecher (1980a)	
Ludlow Creek	17.0192	Nov-Jan	16	Chum salmon spawning	Hiss (1993)	Ludlow
		Feb-Jun	16	Steelhead spawning		
		Jul-Oct	3	Steelhead rearing		
Penny Creek	17.0014	Nov-Jan	31	Coho salmon spawning	Boomer (1994)	Big Quilcene
Penny Creek is managed primarily for hatchery water supply, not natural fish production (Boomer 1994).		Feb-Jun	55	Steelhead spawning		
		Jul-Oct	13	Steelhead rearing		
Ripley Creek	17.0089	Nov-Jan	4	Coho salmon spawning	Hiss (1993)	Little Quilcene
		Feb-Oct	1	Coho salmon rearing		
Salmon Creek	17.0245	Sep-Oct	43	Chum salmon spawning	Data from Beecher (1980a) applied to model of Swift (1979)	Salmon-Snow
		Nov-Feb	21	Coho salmon spawning		
		Mar-May	40	Steelhead spawning	Beecher (1980a)	
		Jun-Aug	9	Steelhead rearing		
Shine Creek	17.0181	Nov-Jan	14	Chum salmon spawning	Hiss (1993)	Ludlow
		Feb-Oct	2	Coho salmon rearing		
Snow Creek	17.0219	Sep-Oct	66	Chum salmon spawning	Data from Beecher (1980a) applied to model of Swift (1979)	Salmon-Snow

Table 6-3. Summary of Theoretical Instream Flow Predictions in WRIA 17 Presented by U.S. Fish and Wildlife Service (Hiss 1993) (continued)

Stream[a]	Stream Number[b]	Months	Theoretical Optimum Flow (cfs)	Species/lifestage	Source	Sub-basin
		Nov-Jan	33	Coho salmon spawning		
		Mar-May	40	Steelhead spawning	Beecher (1980a)	
Snow Creek (con't)		Jun-Aug	9	Steelhead rearing		
East Squamish Creek	17.0183	Intermittent flow or lack of suitable measurement area.			Hiss (1993)	Ludlow
Tarboo Creek	17.0129	Nov-Jan	42	Chum salmon spawning	Data from Beecher (1980a) applied to model of Swift (1979)	Dabob-Thorndyke
		Feb-Jun	40	Steelhead spawning	Beecher (1980a)	
		Jul-Oct	8	Steelhead rearing		
East Fork Tarboo Creek	17.0130	Nov-Jan	3	Coho salmon spawning	Hiss (1993)	Dabob-Thorndyke
		Feb-Jun	8	Steelhead spawning		
		Jul-Oct	1	Steelhead rearing		
Thorndyke Creek	17.0170	Nov-Jan	50	Chum salmon spawning	Data from Beecher (1980a) applied to model of Swift (1979)	Dabob-Thorndyke
		Feb-Jun	45	Steelhead spawning	Beecher (1980a)	
		Jul-Oct	10	Steelhead and coho salmon rearing	Beecher (1980a)	
Unnamed Donovan Creek tributary	17.0116	Stream flow seasonal.			Hiss (1993)	Little Quilcene
Unnamed Mats Mats Bay tributary	17.0200	Nov-Jan	6	Chum salmon spawning	Hiss (1993)	Ludlow
		Feb-Oct	1	Coho salmon rearing		
Unnamed Straits tributary	17.0276	Intermittent flow or lack of suitable measurement area				Miller
Unnamed East Sequim Bay tributary	17.0277	Intermittent flow or lack of suitable measurement area.				Miller
Unnamed Sequim Bay tributary	17.0284	Intermittent flow or lack of suitable measurement area.				West Sequim Bay

[a] Information is presented alphabetically, for ease of reference.

[b] Stream numbering is from Williams et al. (1975).

Note: This table is very similar to Figure 7-1. Instream flow needs for fishery resources in Jefferson County, page 7.36 of the Dungeness-Quilcene Water Resources Management Plan, and relies on the same source. Additional streams not presented in the DQ Report, mostly tributaries to Sequim Bay, have been added.

Wildlife consider the more recent study results to supercede these previous study results where study streams are duplicated.

It is important to note that theoretical optimum instream flow hydrologies are not meant to be used by themselves in the process of setting instream flows. Current and historic flow regime information as well as an assessment of current and historic channel conditions are examples of two other important parameters that need to be considered in the process of setting instream flows. Critical thinking and common sense are necessary when interpreting and implementing these recommendations.

6.3 EXISTING STREAM FLOW RECOMMENDATIONS

Specific instream flow data for each of the 10 WRIA 17 sub-basins is described in Chapters 8 through 17 of this report. The location of sites where toe-width measurements were performed is noted when available in parenthesis.

6.4 RECOMMENDED AND DIRECTIONS IN REGULATORY ACTION/INTENT

The Dungeness-Quilcene Plan recommends that either the Watershed Council or Ecology should establish instream flows for all streams in eastern Jefferson County, except the Big Quilcene River (recommendation J.5.2). The plan recommends that ongoing negotiations between water users, water rights holders and resource managers should work towards improving instream flow conditions in the Big Quilcene River (recommendation J.5.3). A final recommendation is that, should analysis based on IFIM methods, or other "improved" instream flow methods become available, that instream flows developed using this new information also be established by rule (recommendation J.5.4) (Jamestown S'Klallam Tribe 1994).

6.5 EXTENT WHICH CURRENT FLOW REGIMES MEET EXISTING INSTREAM FLOW REQUIREMENTS

For most streams in WRIA 17, there are no existing instream flow requirements that have been incorporated into the Washington Administrative Code.

The City of Port Townsend and the Port Townsend Paper Company have operated the diversion on the Big Quilcene River to comply with a voluntary instream flow arrangement (24 cfs between 1994 and 1997; 27 cfs from 1997 to the present). This voluntary program restricts diversion during low-flow periods. Jablonski (2000) notes that flows in the Big Quilcene River at the municipal diversion between 1994 and 1999 have averaged 50 cfs, and have been recorded as low as 26 cfs during summer chum salmon spawning season. This is well below the predicted "optimum spawning flow" of 180 cfs for chum salmon developed using the IFIM method which did not differentitate between summer and fall chum salmon (Caldwell 1999).

Theoretical optimum instream flow hydrologies and instream flow study results should be compared with hydrologic information. This is an important analysis, since it "grounds" the study results with the hydrologic regime. In the case of flow recommendations, it can be an important indication of the extent to which current flow regimes do, or do not, meet estimates of habitat requirements.

6.6 ASSESSMENT OF DATA QUALITY AND QUANTITY

6.6.1 Data Quality

The WRIA 17 theoretical optimum instream flow hydrologies and study results are not data, but are predictions made using both data and estimates of fish habitat preferences. Assessment of each stream's input data quality for each stream is not possible for the toe-width study results (Ecology and WDFW 1997, 1999; Hiss 1993). This is because data quality is very affected by the investigator's choice of where to measure in the stream, which is difficult to present in the report. It does appear that both sets of investigators followed standard methods for study site selection, measurement, and analysis (Swift 1976, 1979). However, this cannot be verified with existing information.

The Big Quilcene IFIM study report presents enough detail on data collection and modeling approaches to assess data quality (Caldwell 1999). The investigator has followed standard approaches to site selection, data collection, model calibration and analysis. Data quality, model calibration and analysis all appear to be good.

6.6.2 Data Quantity

Taken together, there is enough information to develop optimum instream flows for most of the larger streams and rivers in WRIA 17.

Development of instream flow recommendations is generally done in the following manner: Ecology and WDFW staff, in concert with co-managing tribes, determine which species and lifestage is present in a given stream over the year. They then attempt to craft a optimum instream flows regime that will satisfy, as far as possible, flow needs indicated by instream flow study results. Situations where identified flow needs have the potential for conflict are handled by professional judgement, aided by critical thinking about fish habitat requirements and seasonal flow characteristics.

It appears that there are adequate instream flow recommendations or modeling results to proceed with the setting of instream flows in most of the larger streams in the basin. Two exceptions are Snow Creek and Salmon Creek, where consideration should be given to the collection of additional data, either using the toe-width method or the IFIM method. In addition, it should be considered whether to do an IFIM-method instream flow study on the Little Quilcene River. In all three cases, practicality should be considered. Because an instream flow can only condition a junior water right, doing an instream flow study on a basin closed to further appropriation may not be a high priority.

7. DATA QUALITY, GAPS AND LIMITATIONS

7.1 NATURE AND OVERVIEW OF DATA GAPS

The entire WRIA and all sub-basins have data gaps, which vary in degree. The available data combine to provide a level of understanding of water resources and habitat in both a static and dynamic sense. The level of understanding is likely to never reach a perfect state. Acknowledgment of data gaps, therefore, is an important part of an assessment process. Also, recognition of the magnitude and context of these gaps is critical to a decision-making framework.

The amount of data required will depend on the type of study that would be performed, so the recommendations contained in this section provide only a general overview of missing data. Detailed scoping studies should be performed prior to additional planning or analysis to identify the type and amount of information needed.

This section describes data gaps that generally apply to the entire WRIA 17 area. The water quantity, water quality, habitat and instream flow data gaps for each of the 10 sub-basins are discussed in detail in Chapters 8 through 17 of this assessment. Readers should refer to specific sub-basin sections of this report for a description of sub-basin specific data gaps.

Data gaps that are common to the entire WRIA 17 project area have been broken into separate categories that generally match the technical elements of the watershed assessment. These elements and the respective WRIA-wide data gaps are described below:

7.2 WATER QUALITY

7.2.1 Surface Water Quality

The following data gaps and limitations have been identified for surface water quality in WRIA 17:

- Non-point contaminant source data is typically qualitative and not specifically mapped or identified. Location of previous non-point contaminant sources, the type and date of corrective actions, and the relationship of sources (and corrective actions) to observed water quality monitoring results is generally lacking in existing studies reviewed for this assessment.

- Inventories are needed of specific non-point sources in areas that have experienced water quality problems in the past, or support land use activities that suggest water quality degradation may occur in the future. Digital land cover imagery to identify specific land use cover types and locations would be useful for locating specific areas with land use activities that have high potential to result in non-point source pollution.

- Existing surface water quality data (except for FC and TSS) is not typically related to stream flow so pollutant-loading analysis is generally constrained.

- The Ecology NPDES database should be updated to show the current location and type (stormwater or wastewater) of permitted discharges, and individual NPDES discharge reports evaluated for potential water quality problems. The shellfish harvest GIS layers from DOH showing current harvest status should also be considered.

- An analysis of the existing temperature data collected by Bahls (1995-1997) and JCCD (2000) for areas with documented stream temperature problems should be considered. This analysis may be useful for making broad generalizations between riparian cover conditions, land use type and potential stream temperature problems.

- Very little data exists for potential toxics and/or metals in surface water for the entire WRIA.

7.2.2 Groundwater Quality

The intent of the groundwater quality assessment was to examine water quality parameters of concern, including chloride, nitrate, and known cases of anthropogenic contamination. The data compiled are fairly exhaustive of these parameters. Over the course of this water quality assessment, however, a number of related data gaps have been identified. Most of these data gaps are applicable to all sub-basins in the WRIA, although the level of effort required to fill a data gap may vary between sub-basins. In addition, the importance of filling a particular data gap will vary between sub-basins based on consideration of current and future stresses on the groundwater flow system.

- Groundwater quality data from the WDOH database were neither provided nor considered for this study. Approximately 80 Group A systems rely on groundwater in the WRIA, however data were compiled for only 12 percent of these systems as miscellaneous values excerpted from various consultants' reports. Approximately 225 Group B systems rely on groundwater in the WRIA, however the water quality data required for system approval is often not entered into the WDOH database (Fuchs, pers. comm., 2000). The number of Group B wells in the WDOH database with available digital data was not determined. Chloride data collected by citizens on Marrowstone Island also have not been included, nor have the quality of these data have been assessed.

- Detections of Fecal coliform and E. coli in groundwater were not considered for this study, and available data are very limited. The presence of fecal coliform or E. coli in groundwater typically reflects contamination from sewage or animal wastes. All new wells are sampled for total and fecal coliform before County approval of building permits, and all wells associated with public water systems are sampled periodically. WDOH maintain records of public water system lab tests. County data from new wells are generally unreliable because wells with initial detections are typically disinfected multiple times until coliform is undetected, and then only final sampling results are reported.

- Iron and Manganese are water-quality constituents of concern, both for individual well owners and for purveyors supplying water to larger numbers of people. Treating groundwater to reduce iron and manganese concentrations can be expensive. Very little data groundwater quality data are available for iron and manganese.

- High chloride concentrations in coastal areas are typically considered the result of saltwater intrusion or well completion too close to the transition zone between fresh and salty groundwater. However, other sources of high chloride may occur, as evidenced by high chloride concentrations in inland areas where well completions and groundwater elevations are far above sea level. In some cases, where the causes of high chloride are not readily apparent, more attention could be focused on evaluating the possibility that chloride concentrations are associated with sources unrelated to a current hydraulic connection with the sea.

- The available water quality do not provide comprehensive coverage in all significant areas in the WRIA. Areas exist in all sub-basins where few (or no) wells have been sampled. In addition,

areas occur where a sparse distribution of sampled wells suggests localized problems but does not allow determination of their geographic extent. Among other locations, additional chloride data could improve delineation of the geographic extent of potential saltwater intrusion along coastal stretches of the Ludlow, Indian-Marrowstone, Miller, and West Sequim Bay sub-basins. Similarly, additional nitrate data could improve delineation of the geographic extent of elevated concentrations noted in potentially clustered patterns (e.g. central Quimper Peninsula, upper Chimacum watershed, central Marrowstone Island, general Quilcene area) or in isolated wells sampled near areas of dense development (e.g. south shore of Port Ludlow). In sparsely populated areas, however, additional sampling for nitrate may only serve to confirm the typically "spotty" distribution of nitrate contamination. In most cases, it is not reasonable to expect a high percentage of existing wells to be sampled. The importance of obtaining additional data for particular area depends upon the degree of current and future stress imposed by local land uses and reliance on groundwater as a source of supply.

- While additional sampling may improve the geographic delineation of water-quality problems, the hydrogeologic framework can have a profound influence on the occurrence of elevated chloride, nitrate and anthropogenic contamination. For example, the distribution of high chloride from saltwater intrusion will likely depend on the framework of aquifers and aquitards, hydraulic conditions (e.g. groundwater level elevations), and the locations and rates of well withdrawals. This assessment did not include hydrogeologic interpretation of coastal areas showing high chloride concentrations, however such interpretation should be performed for problem areas requiring further assessment. Hydrogeologic characterization, however, is either absent or preliminary for many areas of the WRIA. Various degrees of additional characterization would be required for all coastal areas where high chloride concentrations are problematic. Consideration of pumping distributions should also be included in saltwater intrusion assessment.

- While this Stage I study identified areas with elevated nitrate concentrations, the geographic extent of elevated nitrates is often unknown due to sparse data (see above). Evaluation of land use controls, such as high densities of residential development, could be used to guide further sampling programs.

- The data available to evaluate changes in groundwater quality over time were limited to several years of recent time-series chloride sampling performed on Marrowstone Island by Ecology and to very sparse, sequential visits to several coastal wells performed by the USGS (and others) over the past three decades. Besides chloride possible monitoring performed by residents of Marrowstone Island, no ongoing time-series monitoring is known to be occurring in the WRIA. For saltwater intrusion, time-series monitoring would be useful to evaluate changes in areas with known high chlorides and/or undergoing rapid groundwater development. Electrical conductivity can serve as a reasonable surrogate for chloride concentration, and groundwater levels should be measured at the same time samples are taken. Given the variability (i.e. "noise") inherent in coastal chloride concentrations, significant amounts of data may be required to discern trends. If possible, measures of pumping withdrawals over time should also be estimated for comparison to water quality. Periodic monitoring of nitrate concentrations may be useful in unsewered areas experiencing rapid residential growth.

- Evaluation of the water quality data compiled for this study have allowed identification of geographic areas of concern; however, resources were not available to examine the causes of elevated chloride and/or nitrate concentrations in problem areas. Managing chloride concentrations in problem areas under pressure of additional development generally requires hydrogeologic interpretation of the local groundwater flow systems. Local studies should consider hydrostratigraphy (the layering of aquifers and aquitards), aquifer properties, hydraulic

heads, well completions and groundwater withdrawals to identify the risks of water-quality degradation via intrusion and the relative susceptibility of different water-bearing zones. Local studies may also help distinguish between saltwater intrusion and natural sources of chloride "trapped" in aquifer materials.

7.3 WATER QUANTITY

The following WRIA 17 wide data gaps may be considered relative to groundwater and surface water quantity data needs and limitations.

7.3.1 Hydrogeology

- More comprehensive aquifer descriptions including discussions of general aquifer/aquitard properties and characteristics, including estimates of aquifer boundaries, summary tables of the wells used to establish boundaries for principal aquifers, and relevant test data. This should include a more detailed description of hydraulic relationships of recharge and discharge (including an adequate understanding of the hydraulic head relationships, gradients, and flows) between aquifers, within aquifer systems, and with surface water.

- The geographic distributions of water use, water allocations, and water-right applications should be used to identify areas under current (or potentially future) stress from pumping withdrawals. Susceptibility to saltwater intrusion, as indicated by high coastal chloride concentrations, should be used to prioritize areas. Declining baseflow, as indicate by streamflow monitoring data (where available) should be used to identify areas impacted by groundwater withdrawals. Groundwater availability problems reported to county health departments or Ecology should also be considered during prioritization.

- Hydrogeologic characterization should be improved in these high priority areas through construction of hydrogeologic cross-sections, differentiation of water-bearing zones and associated pumping withdrawals, evaluation of aquifer properties, and analysis of groundwater flow directions. Dominant factors should be identified that control the hydrologic responses and water quality effects associated with pumping.

- Sub-basins and/or stream segments should be identified where stream baseflow represents a potential limiting factor for potential habitat concerns, and for those areas with significant (current or future) groundwater withdrawals, hydraulic continuity should be evaluated beyond the "relative hydraulic continuity potential" rankings already assigned.

- Further evaluation of hydraulic continuity based on hydrogeologic analyses, similar to those described above. The evaluations should identify key factors likely to control groundwater/surface water interactions, and recommend methods of testing or modeling to substantiate initial conclusions.

- Seepage surveys that directly evaluate hydraulic continuity along selected streams of concern. Seepage surveys are used to identify reaches that gain flow from groundwater discharge or lose flow from streambed seepage. Gains and losses should be quantified in both wet and dry seasons, and be interpreted in light of hydrogeologic characterization of surrounding areas.

- Where seepage surveys have been performed, net values of gains and losses should be incorporated into a water budget analysis for the associate sub-basin. In many cases, water

exchange between aquifers and streams is the principal missing component preventing water budget analysis.

- Conclusions derived from the hydrogeologic characterizations and further evaluation of hydraulic continuity should be used to establish monitoring networks. Groundwater monitoring networks should measure water levels in wells, chloride (or electrical conductivity) concentrations in coastal wells, and should track major groundwater withdrawals (if possible). Optimal locations and water-bearing zones for groundwater monitoring should be identified and arrangements with well owners obtained. Locations for streamflow monitoring should be based on the results of seepage studies and access considerations. Data management procedures should be set up at the same time as monitoring networks.

7.3.2 Hydrology and Surface Water Quantity

- Develop a more accurate flow balance for each sub-basin, with particular attention to estimates of runoff.

- Additional stream gaging information should be obtained to better characterize streamflow regimes throughout WRIA 17. The compilation of stream gaging data is expensive and a prioritization of streams should be considered.

- A more detailed review of surface water uses for irrigation should be performed using field surveys of farms.

- Surface water claims data should be reviewed and the actual water use better estimated.

7.3.3 Water Allocation and Use

- More precise water use data for both surface water and groundwater use, and better information defining the location of uses.

- More comprehensive tracking and analysis of water levels in the various aquifers and evaluate the correlation of water level trends with the various causative factors (e.g. precipitation, production, land use change, etc.).

- Groundwater claims are significant in magnitude relative to confirmed groundwater rights. Verification of actively used claims should be considered so that actively used claims can be transformed into documented water rights.

- Estimation of groundwater use from irrigation should be improved based on interviews with Washington State University extension agents, interpretation of areal photographs, and other methods.

- Estimates or inventories of actual water production from exempt wells and estimates of future changes in exempt well production, when post comprehensive land use projections become available.

- For the entire WRIA, a large portion of surface water use is not known, and for sub-basins other than the Big Quilcene and Little Quilcene River, there is not sufficient information on actual water uses to accurately portray the amount of surface water that may be used.

7.4 FISHERIES RESOURCES AND HABITAT QUALITY

The following WRIA-wide data gaps have been identified for fisheries and habitat:

- The maps in this assessment show the distribution of the various species of salmonids in those streams for which recent habitat assessments and spawning surveys, which were reviewed in this report, are available. For those surveyed streams, the most recent information describing fish distribution is mapped. In most streams, surveys have focused on the distribution of chum salmon and coho salmon, steelhead, and cutthroat trout. Other species, such as chinook salmon, pink (*Oncorhynchus gorbuscha*), and sockeye (*Oncorhynchus nerka*) salmon, which may regularly stray into WRIA 17 streams, but do not comprise self-sustaining populations, are not mapped in this report.

- Spawning surveys have contributed significant information on the current utilization of habitat by adult fish, but there are few comprehensive assessments of the distribution of rearing juvenile coho salmon, steelhead, and cutthroat trout. Comprehensive sampling of the Chimacum Creek system (Bahls and Rubin 1996) has provided an exception to this generality.

- Data on fish habitat for the small streams in WRIA17 is limited. Many small unnamed streams have potential to support salmonids as well as resident cutthroat trout. The cumulative importance of these small streams should be considered. Cataloging of these streams for potential fish presence and habitat would help to provide a more complete understanding of fish distribution.

- Habitat assessment efforts have generally not used a standardized data collection protocol. Standardized data collection and baseline information development will enhance the ability to evaluate effectiveness of restoration measures. Uniform habitat assessment protocols can be used to develop an index of production potential for the existing state of individual streams, and for their restored state, based on the identification of limiting factors for species and life stages.

- Update the existing STREAMNET map with more recent STREAMNET data.

- Evaluate potential coordination and overlap between fish distribution, barrier locations and habitat mapping between SSHIAP and STREAMNET.

- Evaluate the status of culvert barrier correction, and barrier mapping between STREAMNET SSHIAP, and other data sources.

7.5 INSTREAM FLOW

Taken together, there is enough information to develop instream flow recommendations for most of the larger streams and rivers in WRIA 17. It appears that there are adequate instream flow recommendations or modeling results to proceed with the setting of instream flows in most of the larger streams in the basin. Two exceptions are Snow Creek and Salmon Creek, where consideration should be given to the collection of additional data, either using the toe-width method or the IFIM method. A detailed assessment of the data quality and assumptions used for the existing instream flow recommendations was not performed as part of this report.

7.6 GENERAL LAND-USE AND PLANNING DATA

The following WRIA-wide data gaps have been identified for land-use and general planning data:

- Data on actual land cover, future land-use trends associated with forestry and agriculture, and specific land development patterns.
- Existing and future population data was not available for the Clallam County portion of WRIA 17.

8. BIG QULICENE SUB-BASIN

8.1 SUB-BASIN DESCRIPTION

The Big Quilcene River drains a basin of approximately 70 square miles (Figure 8-1). The watershed is primarily under federal ownership, including 27,664 acres under U.S. Forest Service adaptive management and Late Successional Reserves Program. The headwaters include 14,070 acres in the Buckhorn Wilderness, and 1,158 acres in Olympic National Park. A further 3,676 acres are managed by the Washington Department of Natural Resources, and 6,449 acres are in either private or county ownership (BQWAT 1994). The Big Quilcene system includes 18.9 miles of mainstem channel, and 81.9 miles of tributary streams (Williams et al. 1975).

8.1.1 Surface Water Features

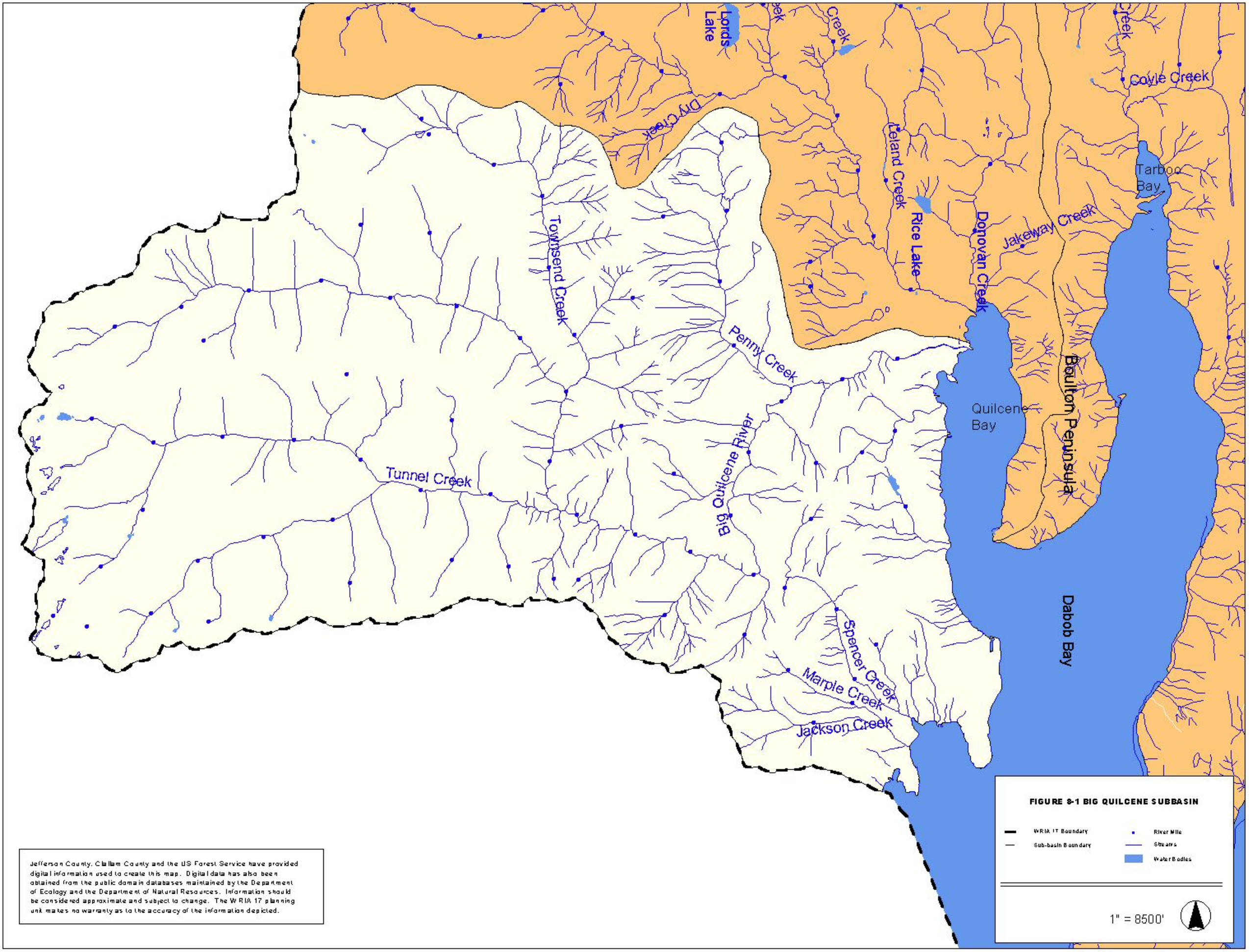
The largest tributaries in the Big Quilcene River sub-basin are Penny Creek, Townsend Creek and Tunnel Creek. Tunnel Creek, the Big Quilcene River and Townsend Creek have headwaters located in high elevation areas (up to 5,600 feet elevation), and their runoff is derived primarily from snowmelt and rainfall. Penny Creek's headwaters are located at a lower elevation (approximately 3,300 ft elevation) and its streamflow is primarily influenced by rainfall. As is typical of drainages on the eastern slopes of the Olympic Mountains, the headwater tributaries of the Big Quilcene River are extremely high gradient, highly confined channels. The middle reaches below River Mile (RM) 4.8 are confined, moderate gradient channels with widened floodplains. Low gradient, unconfined channels characterize the lower 2.5 miles, while the lower 1.0 mile meanders across a broad alluvial fan (Bernthal et al. 1999).

Other independent streams of interest that are located within this sub-basin are Spencer, Marple and Jackson Creek, which drain directly to Quilcene Bay. Surface water features are summarized in Table 8-1.

Table 8-1. Surface Water Features in the Big Quilcene Sub-basin

Main Water Feature	Tributaries	Confluence	Ecology Class
Big Quilcene			Class AA
	Penny Creek	RM 2.8	Class AA
	Elbo Creek	RM 6.0	Class AA
	Mile and a Half Creek	RM 6.75	Class AA
	Three Mile Creek	RM 8.15	Class AA
	Deserter Creek	RM 9.25	Class AA
	Tunnel Creek	RM 9.3	Class AA
	Townsend Creek	RM 11.0	Class AA
	Jolley Creek	RM 13.35	Class AA
	Wet Weather Creek	RM 14.4	Class AA
Marple Creek			Class AA
	Jackson Creek	RM 0.5	Class AA
Spencer Creek			Class AA
Cemetery Drain			Class AA

Source: Williams et al. (1975)


Lords Lake
Dry Creek
Leland Creek
Rice Lake
Donovan Creek
Jakeway Creek
Coyle Creek
Tarboo Bay
Townsend Creek
Penny Creek
Big Quilcene River
Tunnel Creek
Quilcene Bay
Boulton Peninsula
Dabob Bay
Spencer Creek
Marple Creek
Jackson Creek
FIGURE 8-1 BIG QUILCENE SUBBASIN
WRIA 17 Boundary
Sub-basin Boundary
River Mile
Streams
Water Bodies
1" = 8500'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.

8.1.2 Groundwater Features

Hydrogeologic characterization in the Big Quilcene sub-basin is limited to existing maps of surficial geology, a highly generalized geologic cross-section through the area (PGG and EES 1994), generalized discussion of well yields (PGG and EES 1994 and Grimstad and Carson, 1981), mapping of miscellaneous groundwater levels (Grimstad and Carson 1981) and a local hydrogeologic study performed for an inland test well (PGG 1997). The groundwater flow system is dominated by the presence of volcanic bedrock in the upper reaches of the sub-basin with some alluvial or glacial deposits present along major streams. Exhibit 17 shows the generalized surficial geology for the area. In the lower portions of the sub-basin, glacial deposits and alluvium are extensively present near the mouth of the Big Quilcene River and near Jackson Cove. At the mouth of the Big Quilcene River, these deposits comprise the principal aquifer for many of the domestic wells in this area. Potential well yields from these sediments are variable (PGG and EES 1994; Grimstad and Carson, 1981). Farther inland, a hydrogeologic cross-section prepared about 1.5 miles upstream from the bay showed about 70 feet of till overlying advance outwash and interglacial aquifers (PGG 1997).

8.1.3 Land Use

The Big Quilcene sub-basin is primarily national forest. Rural residential zoning occupies approximately four percent of the sub-basin. The town of Quilcene is located in the lower portions of the watershed. Forests occupy approximately 96 percent of the watershed (DOH 1999b). Farms occupy about 3 percent of watershed, mainly along the western marine shore and along the stream corridor. Commercial zoning occupies a total of 48 acres (0.1 percent of the watershed). There are 22 acres of light industrial zoning located just outside of the Quilcene "downtown-core" community. The predominant residential zoning in this watershed (954 acres) is one residence per five acres. Upper portions of the Big Quilcene watershed are protected by the Olympic National Park (Jamestown S'Klallam Tribe 1994) and U.S. Forest Service wilderness designation. Land-use in this sub-basin is shown in Table 8-2.

Table 8-2. Big Quilcene Sub-basin Land Use

Description	No. of Parcels	Acres	% of Total
Rural Residential (1:5)	507	954	2.0%
Rural Residential (1:10)	34	220	0.4%
Rural Residential (1:20)	201	1,529	3.1%
Parks, Preserves, Recreation	25	1,477	3.0%
Olympic National Forest	52	38,355	78.5%
Rural Forest	14	355	0.7%
Commercial Forest	88	5,324	10.9%
Inholding Forest	3	58	0.1%
Military Reservation	2	1	0.0%
Commercial Agriculture	6	109	0.2%
Rural Village Centers (Hadlock, Brinnon, Quilcene)	68	48	0.1%
Light Industrial Zone (Quilcene)	1	22	0.0%
Tidelands	195	123	0.3%
Roads and Right of Ways	76	316	0.6%
Totals	**1,272**	**48,891**	**100.0%**

Source: Jefferson County (2000) and Clallam County GIS. Parcel data is for Jefferson County only.

8.2 WATER QUALITY

8.2.1 Surface Water Quality

Water quality data for freshwater streams in the Big Quilcene sub-basin is summarized in Table 8-3. Selected monitoring locations are shown in Exhibit 3.

Table 8-3. Surface Water Quality Data Available for Big Quilcene Sub-basin

Survey Areas	Parameters		Years Sampled	No. of Sample Locations	Reference
	Temperature	FC			
Big Quilcene	p		1983-1993	NA	USFWS (1988, 1993)
Penny Creek	p		1983-1993	NA	USFWS (1988, 1993)
Big Quilcene		X	1986-1987	3	Welch and Banks (1987)
Cemetery Drain		X	1986-1987	3	Welch and Banks (1987)
Big Quilcene		p	1984	1	Cook (1984)
Cemetery Drain		X	1992-1993	1	Gately (1993b)
Big Quilcene		p	1992-1993	1	Gately (1993b)
Big Quilcene	X	p	1986 – 1989, 1996	3	JCCD (2000)

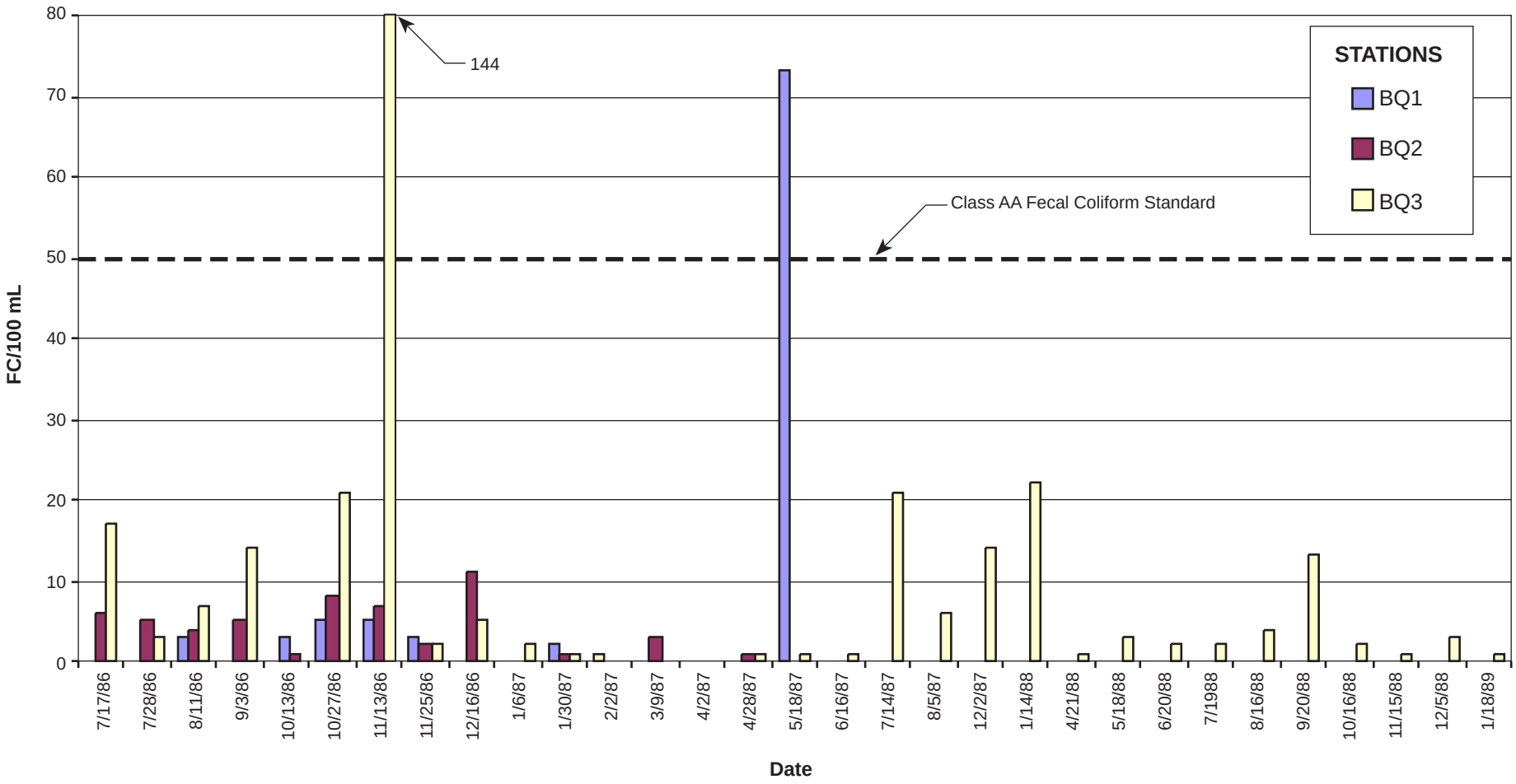
X = water quality was exceeded for at least one sample

p = no water quality criteria was exceeded

The majority of water quality monitoring in this sub-basin has been associated with FC bacteria. Shellfish harvesting has been periodically threatened or restricted due to elevated FC concentrations in Quilcene Bay. Studies by Gately (1993b) have indicated that the freshwater FC standard has historically been exceeded at the Cemetery Drain site, and occasionally near the mouth of Big Quilcene River. Livestock access coupled with malfunctioning OSS have been considered to be the FC loading sources for the lower river reach (Welch and Banks 1987). FC data is shown in Figure 8-2 (JCCD 2000).

Table 8-4 summarizes data from Big Quilcene River from the JCCD database (JCCD 2000). Temperature monitoring at BQ3, conducted on the Big Quilcene River in 1986, 1987, and 1996 (JCCD 2000), is included. Only September 3, 1986 had a temperature above state water quality standards (17.2 C). The USFW temperature records from Big Quilcene River and Penny Creek indicates that these waters have met the state temperature standard (USFWS 1988, 1993).

The City of Port Townsend has periodically tested Big Quilcene River water quality at the City diversion dam as part of their drinking water supply system monitoring program. Previous sampling for volatile organic compounds and synthetic organic compounds revealed that the chemicals for which monitoring was performed were not detected. Inorganic chemical monitoring by the City at the diversion and USFWS at the Hatchery indicate no contamination at these locations. Although turbidity monitored at the diversions of Big and Little Quilcene Rivers show turbidity levels above 5 NTU, water quality results indicate that generally excellent water quality exists in the Big Quilcene River at the City diversion dam.



Source: JCCD

Figure 8-2
Fecal Coliform in Big Quilcene River, July 1986 – January 1989

Table 8-4. Freshwater Quality Data Available for the Big Quilcene River

Site	Dates Sampled	Temp (^oC)	Cond (µmhos/cm)	pH	DO (mg/L)	Turb (NTU)	FC GMV (FC/100ml)
BQ1	8/86 – 5/87	NA					4
BQ2	7/86 – 5/87						6
BQ3	7/86 – 1/89						2
BQ3	7/86 – 3/87	4.4 – 17.2					
BQ3	3/20/91	6.5	104				3
BQ1 (BQ/0.64)	12/31/96	5.4	45.3	6.7	11.4	100	
Irwin Bridge (BQ/4.06)	12/31/96	5.4	42.7	6.7	12.4	32	

Source: JCCD (2000).

8.2.2 Marine Water

Quilcene Bay is an arm of Dabob Bay. Its protected location, warmer water (up to 70 F), and low nutrient concentrations, make it an ideal location for oyster spawning (Welsh and Banks 1987). Marine water quality data for Quilcene Bay is summarized in Table 8-5.

Table 8-5. Marine Water Quality Data Available for the Big Quilcene Sub-basin

Survey Areas	FC	Years Sampled	Sample Locations	Reference
Quilcene Bay	X	1984	16	Cook (1984)
Quilcene Bay	X	1986-1987	5	Welch and Banks (1987)
Quilcene Bay	X	1992-1993	8	Gately (1993b)

X = water quality was exceeded for at least one sample

p = no water quality criteria was exceeded.

In general, water quality in Quilcene Bay is excellent with the exception of the upper Bay, which experiences intermittent FC problems (Welsh and Banks 1987; DOH 1999a). Problems with FC contamination in portions of the bay have been attributed in past studies to natural seal populations, animal keeping practices, and OSS (Cook 1984; Welch and Banks 1987; Gately 1993b). Monitoring by the DOH from 1994 to 1998 (Table 8-6) indicates that FC are not currently a problem in Quilcene Bay (DOH 1999a).

As of 1999, shellfish growing areas in Quilcene Bay are approved except for the north section which is unclassified (DOH 1999a).

8.2.3 Inventory of Potential Surface Water Contaminant Sources

Potential contaminant sources in the Big Quilcene sub-basin include point sources with individual National Permit Discharge Elimination System (NPDES) permits, and non-point sources.

Table 8-6. Fecal Coliform Monitoring in Quilcene Bay, 1994-1998

Station	Sub-basin	No. of Samples	Range	Geometric Mean	Meets Standard
1	Quilcene Bay	37	1.7-31.0	4.2	Yes
2	Quilcene Bay	37	1.7-130.0	3.7	Yes
3	Quilcene Bay	38	1.7-33.0	3.4	Yes
4	Quilcene Bay	36	1.7-110.0	3.6	Yes
5	Quilcene Bay	36	1.7-34.0	3.5	Yes
16	Quilcene Bay	31	1.7-33.0	2.7	Yes
18	Quilcene Bay	36	1.7-33.0	4.4	Yes
19	Quilcene Bay	33	1.7-280.0	5.1	Yes
20	Quilcene Bay	30	1.7-130.0	4.9	Yes
21	Quilcene Bay	29	1.7-79.0	4.3	N/A

N/A – Criteria require a minimum of 30 samples from each station.

Source: DOH (1999a)

8.2.3.1 *Point Sources*

Point sources, each with an individual National Permit Discharge Elimination System (NPDES) permit, are summarized below. Data for NPDES permits is from Ecology (1999a), and does not distinguish between stormwater and/or wastewater permit type.

- Penny Creek Quarry
- Cadman Rock, Inc.
- Jefferson County Public Works
- WDFW Point Whitney
- Quilcene National Fish Hatchery

No specific monitoring data or compliance problems were available for these specific point sources.

8.2.3.2 *Non-Point Sources*

Specific, previously mapped non-point sources are shown in Exhibit 3. The following non-point sources have been identified in the Big Quilcene sub-basin:

- On-site septic systems (OSS) in the lower reaches of the watershed near the town of Quilcene. On-site sewage systems are the only source of sewage treatment in the watershed. Problems are due to 1) old systems that were installed before permits or when standards were less stringent, 2) excessively drained soils, and 3) poorly drained soils. Former problems with on-site septic systems in the areas were associated with direct and indirect discharge to surface water of untreated or partially treated domestic wastewater. Approximately 31 OSS have been repaired in this area over the past ten years (DOH 1999b).

- A small marina operated by the Port of Port Townsend is located two miles south of the Quilcene on the western shoreline of Quilcene Bay. The marina has pump-out facility and bath facilities on shore.

- Agricultural runoff from livestock areas has been identified as a significant source of FC pollution by Cook (1984) and Welch and Banks (1987). Since 1988 the JCCD has overseen the installation of over 14,000 feet of livestock exclusion fencing in the Quilcene Bay watershed.

- Historically, harbor seals have also been a source of water quality pollution in Quilcene Bay. In the late 1980's log booms (near the head of the bay) used for haul-out by the seals were removed; however, seals continue to use a haul out near the entrance to Quilcene Bay (DOH 1999b).

- Forestry related non-point sources have been identified in the Big Quilcene River Watershed Analysis (USFS 1994). Even though there were a small number of specific sources identified, they consisted of areas of erosion that were known to be worsening or were remaining uniform. These areas are shown in Exhibit 3.

8.2.4 Summary of Surface Water Trends and Compliance Problems

Water quality in the majority of the Big Quilcene watershed is good. Temperature in Big Quilcene River and Penny Creek is generally within state water quality standards. FC levels a decade ago were above state standards in Cemetery Drain due to livestock use (Welsh and Banks 1987). Recent temperature, FC, and other water quality data was not sufficiently extensive to determine recent trends in the freshwater streams.

According to the USFS, temperature, nutrients and bacteria remain at low levels throughout the watershed, with the exception of the delta area where more intensive development has occurred (USFS 1994). Elevated FC concentrations are infrequently observed in the lower watershed area and in upper Quilcene Bay; however, the specific factors contributing to elevated FC have typically not been well characterized.

In the lower watershed and in Quilcene Bay, DOH (1999b) found that there was insufficient data to show meaningful FC trends. In general, FC pollution was greatest at the northern most stations in the Bay compared to other areas, suggesting that water quality problems were most likely due to freshwater inputs and minimal tidal exchange.

As noted by DOH (1999b) a variety of actions have been implemented to address non-point pollution in this sub-basin. The following list summarizes significant remedial actions since 1984; however, it is not intended to be an exhaustive or comprehensive list of all remedial actions:

- Watershed planning from 1986-1991, with adoption of the watershed action plan by Jefferson County in October 1991.

- Fencing of livestock along approximately 5,000 feet of stream corridor,

- Watershed management actions including dike setbacks and removals, property buyouts and river restoration along the Big Quilcene River, which are thought to have reduced maximum flood levels, and

- Repair of approximately 31 OSS.

These actions have collectively resulted in all of the classified portions of Quilcene Bay remaining open for commercial shellfish harvest.

8.2.5 Groundwater Quality

Chloride concentrations in the Big Quilcene Sub-basin are mapped on Exhibit 4. Along the coast, elevated chloride concentrations are localized to Jackson Cove. Other coastal wells show background chloride concentrations. In inland areas, elevated chloride concentrations (>100 mg/l) are observed along the Big Quilcene River near its confluence with Penny Creek and mildly elevated concentrations (50 to 100 mg/l) are noted further downstream. The downstream occurrences of mildly elevated chloride occur far inland of the extent to which saltwater travels up the river channel during high tide (Leytham personal communication 2000). Other inland incidences of high chloride have been reported by well drillers in the foothills west of Quilcene (Tillia personal communication 2000).

Few nitrate measurements are available from the Big Quilcene Sub-basin (Exhibit 5). Two out of eleven wells show some degree of elevated nitrate.

Groundwater contamination has been diagnosed at six sites in Quilcene, five of which are due to leaking underground storage tanks and one due to other sources of hazardous materials. The Town of Quilcene straddles the Big Quilcene and Little Quilcene Sub-basins, and no attempt was made to determine which contaminant site is situated in which sub-basin. Among these sites, the information reviewed provides no published evidence that associated groundwater contamination has compromised drinking water for other groundwater users. However, a report on groundwater contamination affecting drinking water (Ecology and WDOH 1999) does note that gasoline was detected in several Quilcene domestic wells, but cleared up after a year of non-use. The source of gasoline contamination was never discovered.

8.3 WATER QUANTITY

8.3.1 Groundwater Quantity

Groundwater recharge estimated for the Big Quilcene sub-basin is approximately 10,300 af/yr, and averages 2.4 in/yr over the entire area. This low rate of recharge is due to the extensive presence of bedrock, which covers approximately 92 percent of the sub-basin. Recharge in non-bedrock areas varies from 10 to 15 in/yr over glacial till, to 30 to 35 in/yr in areas without till cover. Precipitation averages 52 in/yr over the sub-basin, and is likely to cause significant runoff from till and bedrock covered areas. In places, a portion of this runoff is expected to infiltrate into local outwash/alluvial deposits and supplement recharge to the aquifer.

8.3.2 Surface Water Quantity

The quantity of surface water in the Big Quilcene river sub-basin is affected by diversions for both municipal and hatchery use. There are currently two active stream gages in this sub-basin. One is located directly downstream of the City of Port Townsend's diversion dam at RM 9.4. The drainage area at the gage is 49.4 square miles, about 70 percent of the river's 70 square mile watershed. The other active gage is a USGS gage at the Quilcene Hatchery. Another USGS gage was located for a short period of time (1951, 1971-72) near the river's mouth at the town of Quilcene.

Streamflow data from the USGS and diversion data from the City of Port Townsend was obtained and graphed. Figure 8-3 shows average monthly flows recorded at the USGS gage and average monthly diversions recorded by the City. The average diversion by the City is approximately 24 cfs. The City currently reduces their diversions when streamflow drops below 51 cfs and stops diverting when

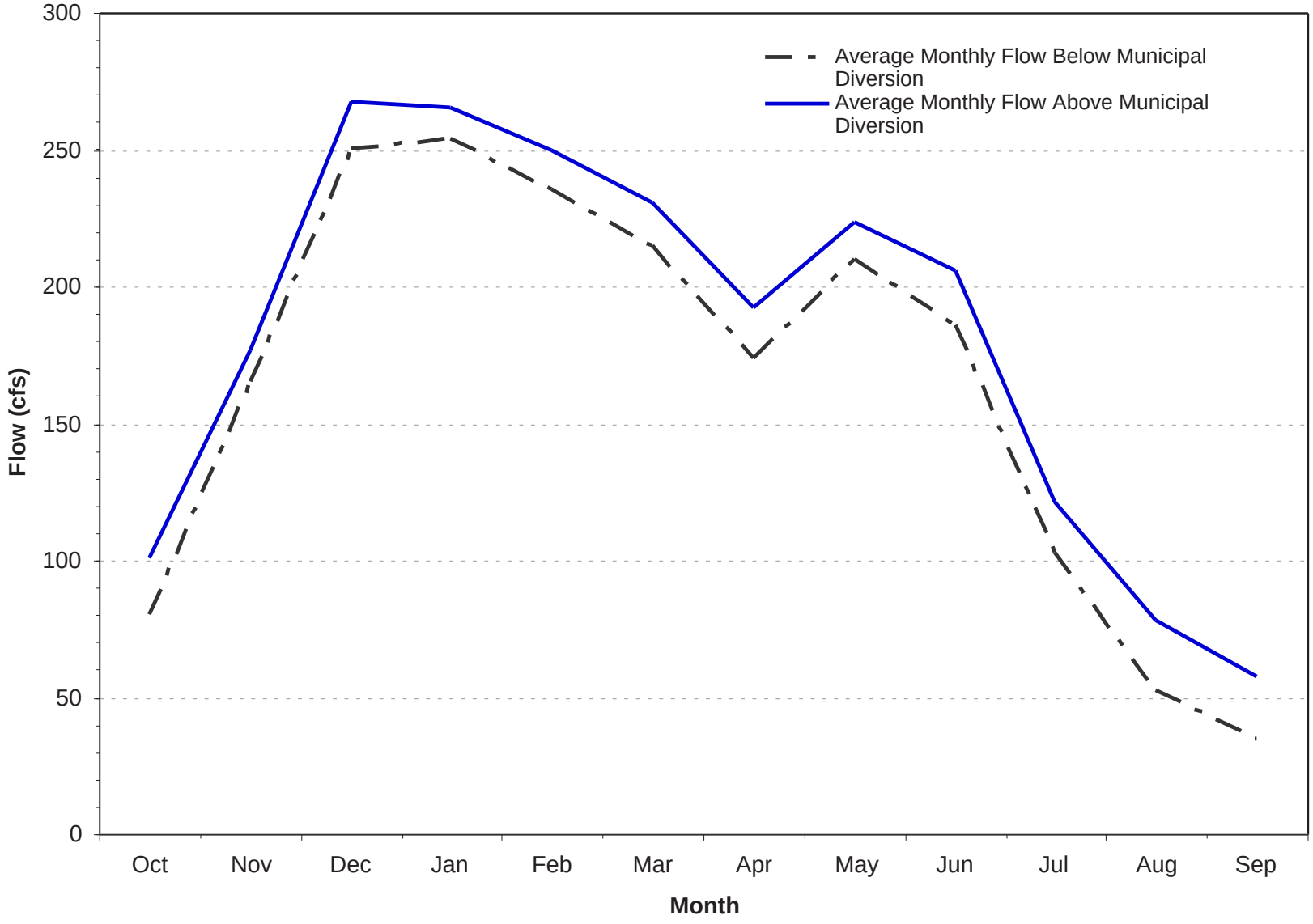


Figure 8-3
Big Quilcene River Diversion near Quilcene
USGS Gauge 12052210
Period of Record 1993-1999

streamflow reaches 27 cfs (Jablonski 2000). The reduction is voluntary, because the City water right does not have a minimum flow requirement.

The USFWS operates a fish hatchery that diverts water from the Big Quilcene River at River Mile 2.8, located just upstream of Hwy 101. Their water right (and diversion) is conditioned on meeting an instream flow in their bypass reach, which is approximately 3,000 feet. The hatchery is entitled to a water right of 15 cfs at all times and can withdraw up to 40 cfs from the Big Quilcene River provided 50 cfs flow is maintained in the bypass reach from July 1 through the end of February, and 83 cfs flow is maintained the remainder of the year (Jablonski 2000).

An analysis of the Big Quilcene stream gage record was performed to determine how streamflow has varied historically throughout the year. A statistical analysis using recorded daily streamflow was performed that produces low, median, and high flow exceedance probability estimates for incremental dates during the year. Low flow is defined as the 90 percent exceedance probability, and is equal to the flow rate that occurred 9 years out of 10 for a particular period of time. The median flow is defined as the 50 percent exceedance probability, and is equal to the flow rate that occurred five years out of ten. High flow is defined as the 10 percent exceedance probability, and is equal to the flow rate that occurred one year out of ten.

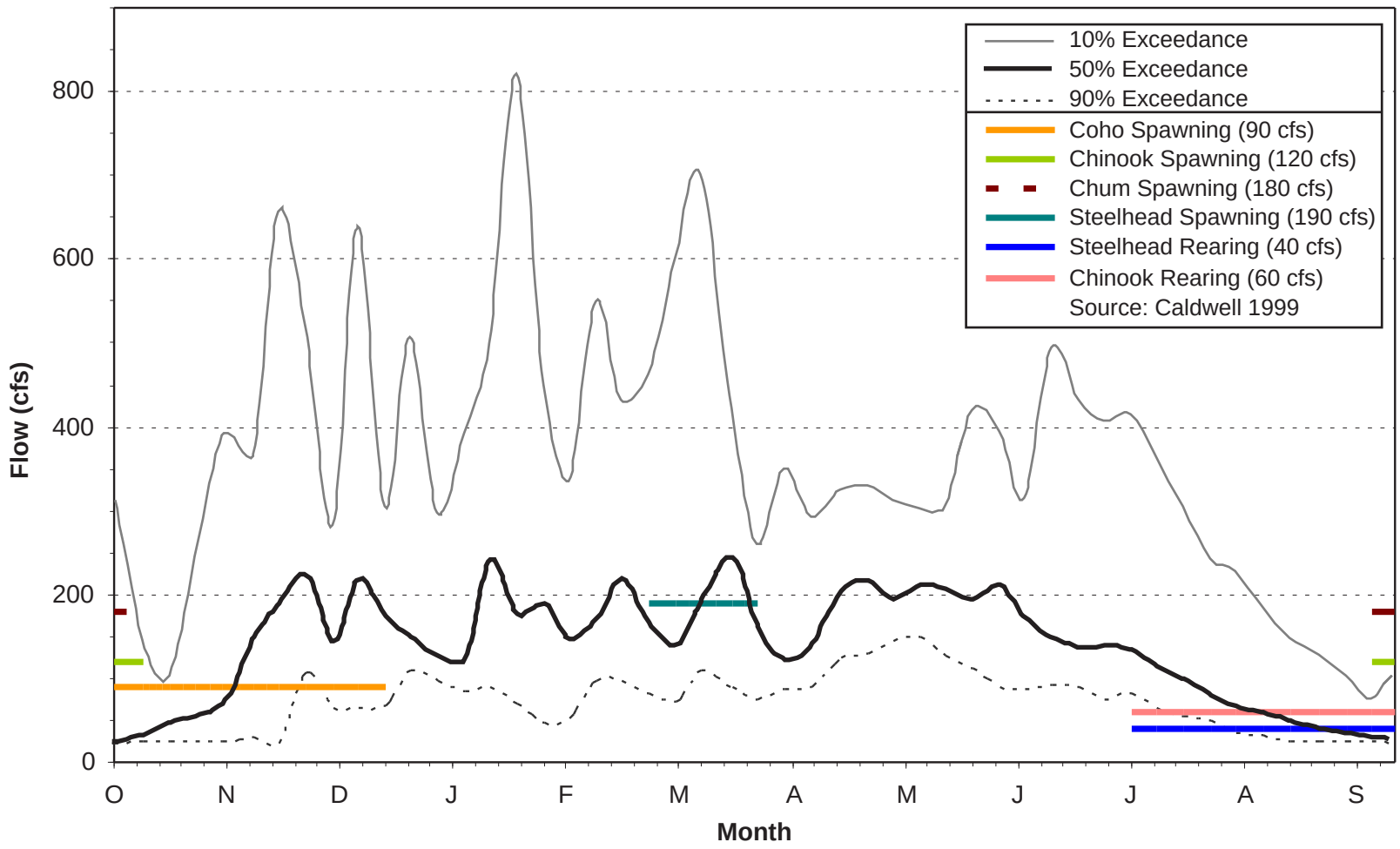
Figure 8-3 shows the flow exceedance characteristics of the Big Quilcene River. Figures 8-3 and 8-4 show that the peak annual flow at the gaging station typically occurs in December and January, followed by a smaller peak in the May through June time frame at the peak of the spring snow melt. The lowest annual flows typically occur in September or October prior to the start of fall rains in the higher elevations of the watershed.

Theoretical optimum instream flow for the Big Quilcene River and other streams in the sub-basin were summarized in the Draft Instream Flow Data Summary (Parametrix 2000). The theoretical optimum instream flow for the Big Quilcene River are plotted on Figure 8-4 along with the flow exceedance curves. The optimum chum salmon spawning flows are less than the 10 percent exceedance values for the Big Quilcene River during the months they are needed (September to October). The steelhead spawning flows are approximately the 50 percent exceedance flow during the months they are needed (February to May). The optimum coho salmon spawning flows have exceedance values ranging from about 10 percent in October to 90 percent in December. The optimum flows for chinook salmon and steelhead rearing have exceedance values ranging from 90 percent in July to about 10 percent in September. It should be noted that the instream flows presented appeared to have been formulated based upon the hydraulic conditions of the Big Quilcene River just below the municipal diversion. The river has approximately 30 percent more drainage area at that point and flows would also be higher than shown on Figure 8-3. Studies to characterize streamflows at the mouth of the Big Quilcene River are currently in progress by the City of Port Townsend.

8.3.3 Estimate of Water Use and Allocation

8.3.3.1 *Groundwater Use and Allocation*

Exhibit 11 shows the spatial distribution of groundwater use in the Big Quilcene sub-basin. The total groundwater withdrawal, assuming a domestic use of 250 gpd, is 302 af/yr. Approximately 40 percent of this total use is estimated from water rights and claims for irrigation purposes, and is qualified as being "lower accuracy" data. The remaining 60 percent (182 af/yr) is based on various sources for domestic and commercial uses, and is believed to be relatively high quality data. Given the general reliance on



Note: Flow data is combined from gage near town of Quilcene (1971-1972) and gage below the municipal diversion (1994-1999).

Figure 8-4
Theoretical Optimum Habitat and Flow,
Big Quilcene River Below Diversion near Quilcene
USGS Gauge 12052210
Period of Record 1971-1972, 1994-1999

septic systems in the sub-basin, the consumptive portion of these domestic and commercial withdrawals is likely to be much lower than the total amount withdrawn.

In the Big Quilcene sub-basin, 17 groundwater rights have been issued for a total of 712 af/yr. The spatial distribution of groundwater rights is shown in Exhibit 9. Figure 8-5 shows a pie chart of groundwater rights by use that shows approximately 72 percent of the total allocation is for fish propagation. It should be noted that groundwater withdrawn for fish propagation is typically returned to the river. The remaining rights are dominantly issued for domestic multiple and single uses, followed by irrigation.

Approximately 589 (exempt) single family wells are estimated for the Big Quilcene sub-basin, translating to a potential exempt allocation of 3,298 af/yr. However, only a small portion of this exempt allocation is likely to be actually put to use.

There are two groundwater right applications in the Big Quilcene sub-basin, requesting a total Qi of 2,020 gpm. A request for 2,000 gpm is for fish propagation, and 20 gpm is requested for domestic multiple and fire protection.

There are 112 groundwater claims in the sub-basin. Table 4-3 lists claims by use, and shows that only 11 of these claims list irrigation as a principal use. Typically, only a portion of claims listing irrigation as a purpose-of-use list numbers of irrigated acres. In the Big Quilcene sub-basin, water use associated with the reported numbers of irrigated acres amounts to 90 af/yr. If each claim is also assumed to include a domestic use, total claimed groundwater can be estimated at about 200 af/yr. The portion of these claims that have been actually put to use, and would qualify for a water right, is unknown. A map of the spatial distribution of groundwater claims is presented on Exhibit 10.

8.3.3.2 *Surface Water Use and Allocation*

Water is diverted at RM 9.3 for the City of Port Townsend and the Port Townsend Paper Company, and at RM 2.8 for the Quilcene National Fish Hatchery. Water use by the hatchery is consumptive for approximately 0.3 miles between the diversion and the outfill. Table 8-7 shows the relative distribution of consumptive use surface water rights in the Big Quilcene sub-basin. The largest use of surface water is for manufacturing and municipal use, comprising 74 percent of the total instantaneous quantity and 97 percent of the total annual quantity. The next largest use is for irrigation, followed by domestic single use and domestic multiple use. Figure 8-4 presents the relative distribution of surface water rights. The total consumptive use of surface water rights are 33.39 cfs and 22,244 af/yr annual quantity. A quantity associated with the City of Port Townsend diversion was not on the database, but the City measured 15.5 cfs of use in 1999. Claims data indicate that 2.86 cfs are claimed with an annual quantity estimated at 286 af/yr. The claims data is not reflected on Figure 8-5. The spatial distribution of surface water rights (Qa), claims (Qi), and claims (Qa) are shown in Exhibits 12, 13, and 14, respectively.

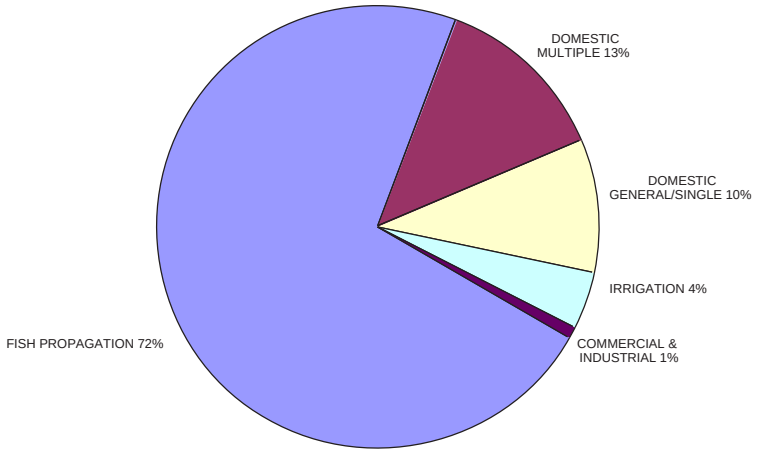
Table 8-7. Analysis of Surface Water Allocation in Big Quilcene Sub-basin

Purpose	Percent (cfs)	Percent (ac-ft)
CI	0%	0%
DM	2%	0%
DS	10%	0%
FR	0%	0%
IR	13%	2%
MU/CI	74%	97%

Explanation of Purpose Codes:

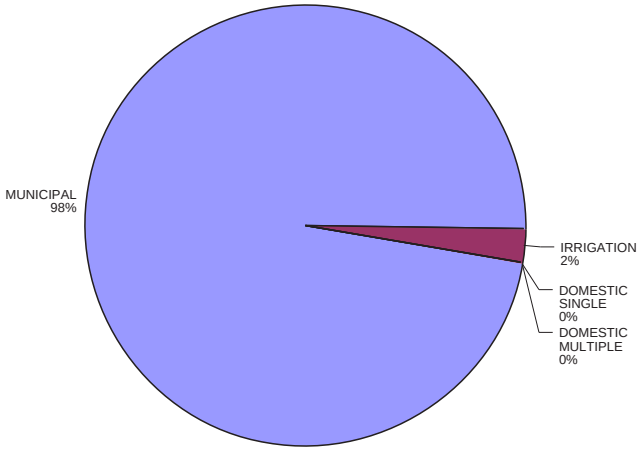
CI	Commercial and Industrial Manufacturing	FS	Fish Propagation	MI	Mining
DM	Domestic Multiple	IR	Irrigation	ST	Stock Watering
DS	Domestic Single	FR	Fire Protection	MU	Municipal

GROUNDWATER RIGHTS (QA) BY USE



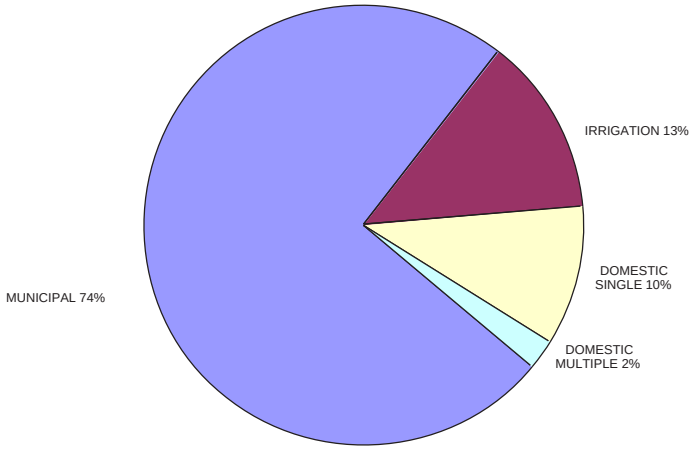
Note: total allocation = 712 af/yr, accounted by use = 712 af/yr, domestic exempt wells = 3300 af/yr

SURFACE WATER RIGHTS (QA) BY USE



Note: total allocation = 565 af/yr, accounted by purpose 565 af/yr, additional non-consumptive rights 18128 af/yr

SURFACE WATER RIGHTS (QI) BY USE



Note: total allocation = 33.4 cfs, accounted by purpose = 40.3 cfs, additional non-consumptive rights = 89 cfs

Source: Ecology WRATs database

Figure 8-5
Big Quilcene Sub-Basin Groundwater and Surface Water Rights and Use, Consumptive Use Only

8.3.4 Hydraulic Continuity Potential

Relative hydraulic continuity potential (RHCP), as shown on Exhibit 17 is ranked as "low" in the bedrock and till-covered areas that dominate the sub-basin and "medium" in the alluvial and recessional outwash deposits along the Big Quilcene River as it emerges from the foothills. Hydrogeologic investigation performed over a mile upstream from the bay suggests that the Big Quilcene River cuts into a till unit that overlies the principal aquifer in this area and that groundwater flow directions are towards the river (Pacific Groundwater Group 1997). It could not be determined whether the river cuts completely through the till to intersect the underlying principal aquifer. Where the river does cut through the till, RCHP should be considered "high". Because of this uncertainty, it was ranked as "medium-high" on Exhibit 17. RCHP was ranked as "high" near the river's mouth, because the thick sequence of alluvial and outwash sediments is used by many wells and comprises the principal aquifer in this location.

A similar situation may occur in the alluvial and outwash deposits near Jackson Cove. The deposits appear to cut into glacial till. Insufficient information was available to determine whether these deposits comprise a shallow or a principal aquifer. RCHP was ranked as "medium" in this area.

8.4 FISHERIES AND FISH HABITAT

Anadromous salmonids in the Big Quilcene River include coho salmon, summer and fall chum salmon, steelhead, and coastal cutthroat trout (Exhibit 18). Chinook salmon, pink, and sockeye salmon may regularly stray into the system but do not comprise self-sustaining populations. Chum salmon and coho salmon access the mainstem Big Quilcene up to RM 2.7, where a weir operated by the QNFH blocks further passage into the mainstem. Winter steelhead and cutthroat may pass the electric weir at high flow, when the power is turned off, and access the mainstem up to RM 7.4 where a natural falls creates an impassable barrier. Historically, coho salmon utilized the mainstem up to RM 4.8 where a seasonally impassable falls blocks passage. Salmonids in the upper watershed include resident coastal cutthroat and brook trout. There is no evidence that bull trout are present, but very little assessment has been done to date. The habitat quality of high altitude lakes and streams, where fisheries were formerly enhanced by regular stocking of catchable rainbow trout, has not been assessed (BQWAT 1994). Fish populations and water quality assessments have been conducted on many of these lakes (Bahls 2000 personal communication), but these data were not reviewed for this assessment.

8.4.1 Salmonid Stocks

8.4.1.1 *Summer and Fall Chum Salmon*

Summer chum salmon in the Big Quilcene and Little Quilcene rivers have not been genetically differentiated, so they are treated as a single stock. It is a native stock, and a composite of natural and hatchery production. Records from the QNFH show that the number of females collected for broodstock ranged up to 2,707 between 1912 and 1937. Spawning escapement in the Big Quilcene fell in 1969, and for the next ten years fluctuated below 3,000 (Figure 8-6). Escapement subsequently declined, and was less than 100 between 1979 and 1991, then increased dramatically after 1993, and has averaged over 5,000 for the period between 1995 and 1999. This increase has been at least partly attributable to the supplementation program that was begun at the QNFH in brood year 1993.

There are two genetically distinct stocks of chum salmon in the Big and Little Quilcene systems. Summer chum salmon are part of the Hood Canal aggregate, and are distinguished only from the Union River stock. A summer chum salmon supplementation program began at QNFH in brood year 1993. Fall

chum salmon in these systems are mixed native/non-native origin, and a composite of hatchery and natural production (WDF et al. 1993). Big Quilcene hatchery fall chum salmon are genetically distinct from other Hood Canal fall stocks. The recent trend in fall chum salmon spawning escapement to the Big Quilcene River is shown in Figure 8-7. Brood stock is still collected, with production intended to support terminal fisheries in Hood Canal. The current production goals for the QNFH include 2.2 million fall chum salmon released to the Big Quilcene River, 373,000 summer chum salmon released to the Big Quilcene River, and 103,000 eyed summer chum salmon eggs for transfer to Big Beef Creek.

8.4.1.2 *Coho Salmon*

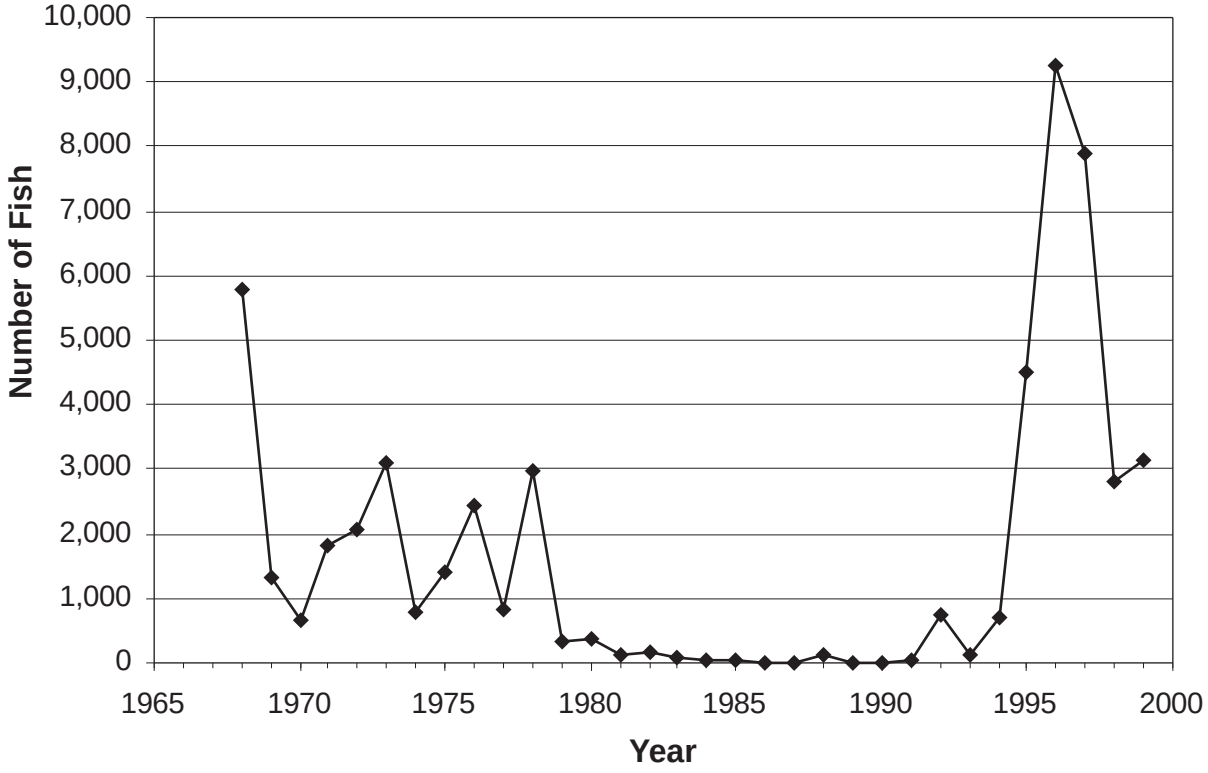
Naturally reproducing coho salmon in the Big and Little Quilcene rivers and other streams draining into Quilcene and Dabob Bay are combined into a single management unit. Spawning escapement is estimated in aggregate, based on annual surveys of index reaches in Tarboo Creek and the Little Quilcene River. Supplemental surveys have been conducted in recent years (see below) that provide additional data on spawning distribution and approximate numbers in several tributaries. Escapement has ranged from 200 up to 1,200 between 1986 and 1998, and the terminal run size (i.e. that number of adults entering Hood Canal, has ranged from 300 to 7,700 in that period.

The QNFH raises early-timed run of coho salmon, primarily for release into the Big Quilcene River. Current hatchery production objectives include the release of 450,000 smolts into the Big Quilcene River, 200,000 fingerlings into tribal net pen facilities in Quilcene Bay, and up to 500,000 eggs which are transferred to the George Adams Hatchery and then into net pens in Port Gamble Bay. Dungeness Hatchery and George Adams Hatchery (Skokomish River) have also supplied coho salmon to the Quilcene Bay pens in recent years. The primary purpose of the Quilcene Hatchery program is to enhance terminal fisheries.

There is evidence that these hatchery-origin coho salmon stray into streams, most often those in the immediate vicinity of Quilcene and Dabob Bay. The extent to which they have intermingled with the native stock is unknown (Lichatowich 1993a). The natural stock was judged to be depressed in the SASSI document (WDF et al. 1993), and subsequent concern over underescapement and its causes in Hood Canal were raised by the Pacific Fisheries Management Council (PSSSRG 1997).

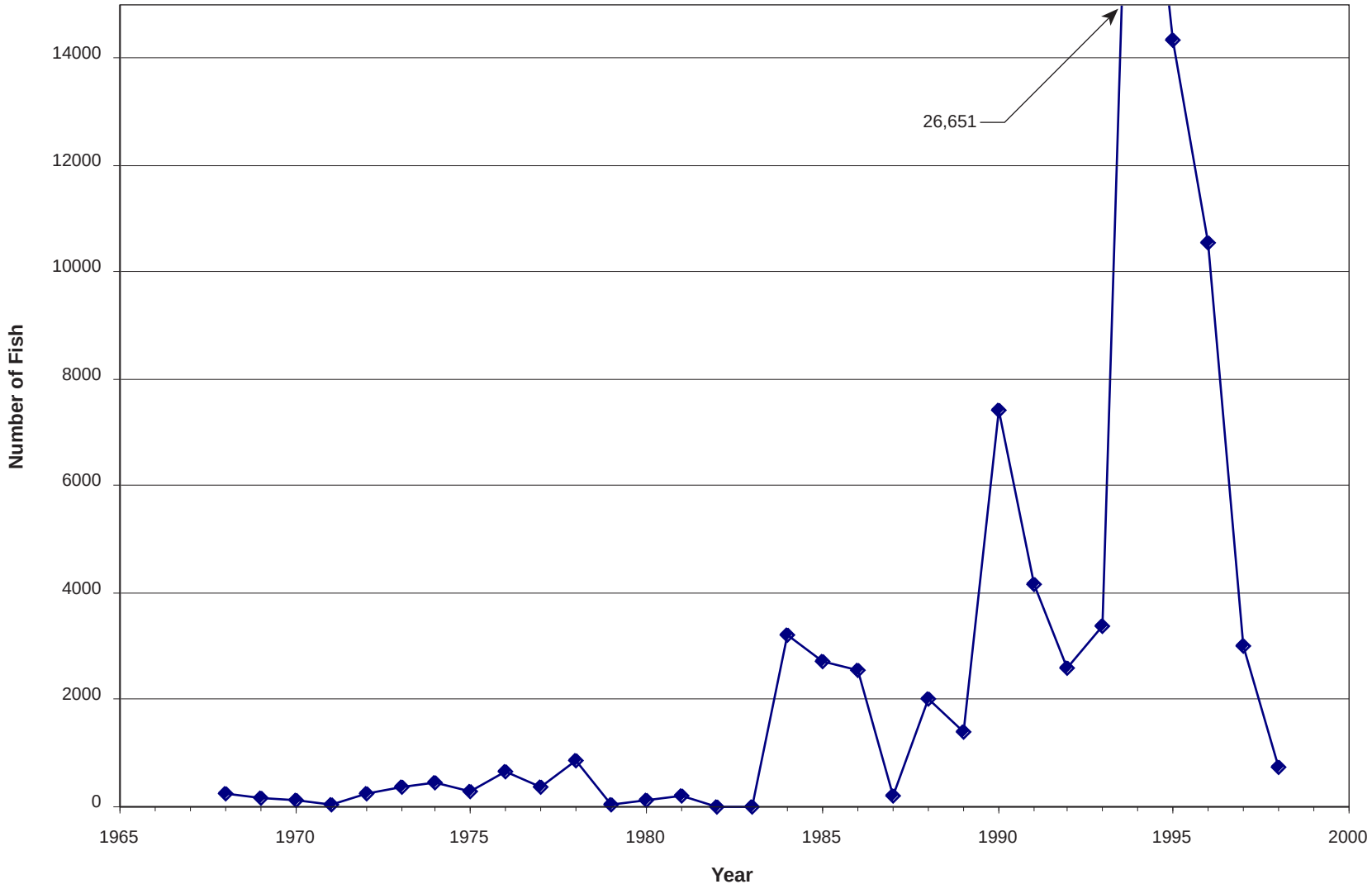
Supplemental escapement surveys confirm that a small and annually variable number of native coho salmon and some hatchery- or pen-origin coho salmon spawn in the smaller tributaries of the Big and Little Quilcene rivers, and independent streams that drain into Quilcene Bay and Dabob Bay. Analysis of a small number of scales confirmed that some of these coho salmon were of hatchery or net pen origin (Bahls 1996). Surveys of Leland Creek from 1992 to 1996 (Bahls 1994, 1995, 1996) found from zero to 24 coho salmon spawning in the lower 1.3 miles. Because they were observed spawning from early December through early January, they were believed to be of native origin.

Coho salmon spawning escapement to streams entering Quilcene Bay and Dabob Bay is estimated in the aggregate from annual surveys of index reaches in Tarboo Creek (tributary 17.0130 RM 0.0 – 0.9) and the Little Quilcene River (RM 3.0 to 5.3). Reliable estimates are available for the years since 1986. Escapement ranged between 200 and 600 from 1986 to 1994, then increased in 1996, 1997, and 1998 to between 800 and 1200 (Figure 8-8). Recovery of coded-wire tagged coho salmon at the QNFH rack, which were reared in the Quilcene Bay net pens, suggests that these pen-reared fish may comprise from 10 to 20 percent of the natural escapement in adjacent streams. Ruggerone (1997) reported that net pen-reared coho salmon comprised 75 percent of the coho salmon sampled within five miles of pen facilities, and 50 percent of those sampled between 5 and 10 miles away from pens, in Port Gamble and Quilcene Bay. Hatchery-origin coho salmon strayed to a lesser extent but comprised an additional 9 to 22 percent of recoveries within 10 miles of the nearest hatchery. Bahls (1995, 1996) reported that over 80 percent of



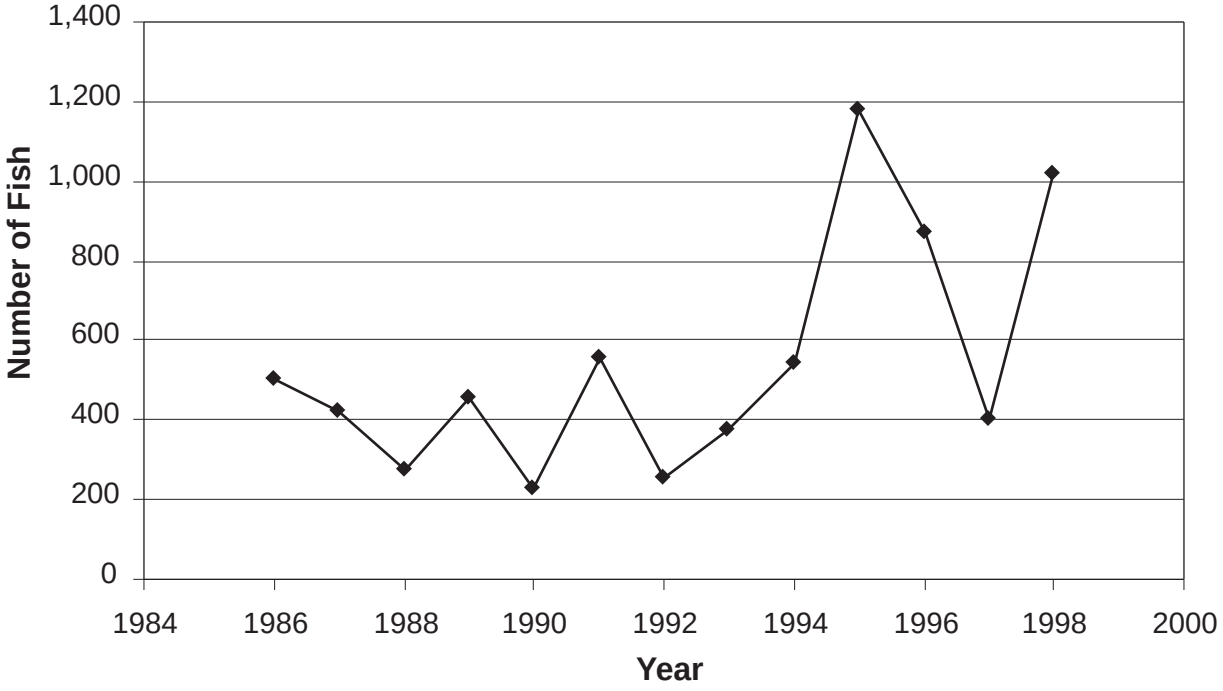
Source: Ames et al., 2000.

Figure 8-6
Summer Chum Spawning Escapement to the Big Quilcene River, 1970-1999



Source: WDFW, unpublished data.

Figure 8-7
Fall Chum Spawning Escapement to the Big Quilcene River



Source: Hood Canal Joint Tech. Comm., 1999.

Figure 8-8
Coho Spawning Escapement to Streams Entering Quilcene Bay and Dabob Bay, 1986-1998

the spawning coho salmon sampled in northern Hood Canal were of hatchery or net-pen origin, but this conclusion was based on very small sample size. Carcass sampling in 1996-97 showed that hatchery or pen-origin coho salmon comprised 40 percent, 50 percent, and 14 percent of spawners in northeast Hood Canal, Quilcene-Dabob, and Chimacum Creek, respectively.

Coho salmon that spawn naturally in the Big and Little Quilcene Rivers, and in adjacent streams such as Donovan Creek and Tarboo Creek, are thought to be of native origin. They return in September and October, with peak of spawning in early November. They are distinct from the early-timed coho salmon stock reared at the Quilcene Hatchery, which stock returns in August and September to the terminal area and has a peak of spawning in October.

8.4.1.3 *Chinook Salmon*

Spring chinook salmon production in these sub-basins was associated only with the QNFH experimental program, which operated for brood years 1978 to 1993. Fall chinook salmon production is not differentiated from the Hood Canal aggregate. There is not currently a self-sustaining stock of fall chinook salmon in the Big Quilcene. The SASSI review (WDF et al. 1993) did not recognize any native chinook salmon stock in either the Big or Little Quilcene systems. Returns of spring chinook salmon to the Quilcene Hatchery, which in the late 1980's ranged from 100 to 200 (Zajac 2000 personal communication), no longer occur since the enhancement program was terminated in 1996. QNFH began broodstock collection of fall chinook salmon from the Big Quilcene, Little Quilcene, and Duckabush rivers in 1911, but the egg supply was insufficient to meet program goals. A mid-Columbia River (Cook) stock was imported, and released in 1926. The fall chinook salmon program was terminated in 1977. Fall chinook salmon have been observed very infrequently at the Quilcene Hatchery rack since 1990 (Zajac 2000 personal communication).

8.4.1.4 *Steelhead*

Winter steelhead escapement is not regularly monitored in the Big Quilcene river, or adjacent tributaries in Quilcene Bay and Dabob Bay, so their status is unknown (Lichatowich 1996). Very few steelhead were counted during supplemental surveys of several tributaries (Bahls 1995, 1996, 1997b, 1998).

The status of winter steelhead stocks in the Big and Little Quilcene systems is unknown (WDF et al. 1993). Sport catch data from the 70's show up to 200 winter steelhead harvested in the Big Quilcene River, and also a few summer steelhead. It is unlikely that summer steelhead are self sustaining, because these systems lack the required holding habitat (i.e. deep pools) during the base flow season.

8.4.1.5 *Other Species*

Sockeye are occasionally observed in the Big Quilcene River, as they are in many streams river in Puget Sound. The U.S. Bureau of Fisheries surveys mention sockeye in the South Fork of the Skokomish River. Pink salmon, observed in odd years at the QNFH are likely strays from the Duckabush and Hamma Hamma rivers.

Anadromous and resident coastal cutthroat are present in these systems. The anadromous form is of special concern due to dramatic declines in abundance, but reliable estimates of abundance are not available. Many cutthroat stocks have been reared at the QNFH and outplanted into the Big Quilcene and other systems. In the 1920's, a stock was imported from Montana, and 20,000 were outplanted in 1964. WDFW has planted westslope cutthroat in alpine lakes in the drainage, so introgression is probable.

There is no data to suggest that the Big Quilcene population is genetically distinct. Isolation in some streams is possible due to water management. A barrier at the mouth of Penny Creek, for example, prevents any upstream migration.

Hass and McPhail showed that Dolly Varden/Bull trout- can occur sympatrically and maintain distinct populations. Dolly Varden have a greater tendency toward anadromy, but bull trout specimens collected elsewhere in Puget Sound indicate salt tolerance (Cavender 1978). Marine movements of bull trout are limited. The nearest confirmed bull trout population is isolated in the North Fork Skokomish River and Cushman Lake. The bull trout status review (UFWS 1998) excluded Olympic populations from the listed Distinct Population Segment. It is unlikely that bull trout are established in the Big Quilcene or adjacent systems. A limited assessment of several streams in Hood Canal and the Strait of Juan de Fuca region (Donald 1991) did not find bull trout in Hood Canal streams.

8.4.2 Habitat Assessment

The habitat assessment includes information about the mainstem reaches of the Big Quilcene River that are accessible to anadromous salmonids. In addition limited information is included about potential anadromous and resident salmonid habitat in Penny Creek, Townsend Creek, and Tunnel Creek, and for the following independent streams: Marple Creek, Jackson Creek, and Spencer Creek.

8.4.2.1 *Big Quilcene River*

The Ambient Monitoring surveys of the Big Quilcene River, conducted under the TFW program in 1995 (Bernthal et al. 1999) divided the mainstem into five segments between the mouth and RM 3.3: Segment 1, RM 0.0 to 0.2; Segment 2, RM 0.2 to 1.3; Segment 3, RM 1.3 to 2.8; Segment 4, RM 2.8 to 3.2; and Segment 5, RM 3.2 to 3.3. River mileposts are mapped on Exhibit 18.

Channel Condition

The first segment and most of the second (up to RM 0.8) is almost all riffle, except for a single pool at RM 0.2. The channel is unconfined, with gradient less than 1 percent. Segments 1 and 2 contain few pieces of LWD, and the stream bed is 100 percent gravel. Pool quality was rated poor.

Segments 2 and 3 are braided and unstable, with moderately confined side channels, one to two percent gradient. Pools are infrequent; they comprised 23 percent and 35 percent of the channel area of Segments 2 and 3, respectively. Segment 2 has few pieces of LWD. Segment 3 has logjams, but few of sufficient size to be classed as key pieces. Gravel abundant in the channel throughout Segments 2 and 3, and so spawning habitat quality was rated good.

Segment 4, immediately above the QNFH weir, was not surveyed because anadromous fish usage is prevented. The channel is moderately confined with a gradient of one to two percent.

The channel in Segment 5 is braided and moderately confined, with gradient of one to two percent. It contains a higher amount of LWD and logjams than the lower segments, but the logs are small diameter, and unstable. Pools are abundant in Segment 5, making up 53 percent of the channel, but all are 1 m or less in depth.

Bernthal et al. (1999) did not assess pool forming factors in the Big Quilcene, and the channel substrate was not quantitatively sampled to determine particle size composition.

The recent Watershed Analysis (BQWAT 1994) assessed habitat condition in 13 segments of the Big Quilcene mainstem that comprise currently utilized or potential habitat for anadromous species from the estuary to RM 7.6. Conditions in each segment were rated for 13 parameters. Overall LWD density was estimated to be 80.5 pieces per mile, which is near the regional average for similar-magnitude streams (83 pieces per mile). However, like the subsequent TFW assessment, the Analysis concluded that LWD was limiting spawning and rearing habitat in the lower reaches. Sampling was not done to measure substrate size composition (i.e. percent fines) or scour rate. In all segments, most condition parameters were rated poor.

Channel migration and bank cutting was observed to be common between RM 1.0 and 3.5. The lower two miles are subject to frequent flooding caused by aggradation, channelization, and channel straightening. The lower one mile was diked in 1880's to enable agricultural use, and is included on the Ecology 303(d) list due to reduced streamflow and impaired habitat. Below RM 4.8, 38 percent of the riparian zone has been developed as road or dikes, or cleared for agriculture. A portion of channel up to RM 4.8 has been either dredged, diked, or bank hardened.

Sedimentation and Channel Migration

Processes of sediment transport and accumulation in the lower Big Quilcene River were described by Williams et al. (1995). Fine particles are carried as suspended load, and large particles move as bed load, dependent on the current velocity. Floods typically move suspended load all the way to the mouth where it is deposited on the delta and in deeper water, but suspended load may be deposited upstream where the stream overtops its banks. Coarse sand tends to be deposited on the floodplain, close to the bank, particularly where vegetation reduces velocity. In natural systems bank erosion is more common in locations where flows are deep and velocity is high, such as at the outside of meanders. Deposition occurs in locations where velocity is lower such as the inside of meander and on floodplains. In modified systems, such as the Big Quilcene, flood flows are confined to the channel, where greater channel depth and velocity result in bed scour and erosion.

Deposition of alluvium over thousands of years has resulted in a relatively wide, flat valley in the lower four miles of the Big Quilcene River. One mile above the mouth an alluvial fan has formed. The river splits into small distributary channels as it crosses the delta. The basic form of the channel is naturally maintained, although occasional floods alter distributary channels. Natural levees tend to contain the channel, which aggrades and extends farther into the bay. When obstructions occur, (e.g. log jams), the natural levee may be breached, and the channel switches. The channel also meanders in association with buildup of gravel bars and pools. A network of abandoned and active channels has been built up across the floodplain. Vegetation traps sediment when overbank flow occurs through the adjacent riparian area. Side channels tend to be scoured, rather than filled, during floods, and provide suitable spawning habitat.

The increased sediment loading from the upper watershed, which was high between 1971 and 1993 will take several decades to be transported downstream. To control flooding, the lower channel has been straightened and confined within levees, which are built from excavated riverbed material. Though most of these levees will not contain a major flood, they reduced the frequency of flooding and tend to increase the frequency and period of bed scour and deposition. The mouth of river has also straightened, and become less hydraulically efficient, so the delta has moved 1,700 feet into the bay (Ames et al. 2000).

Aggradation is a common problem related to high sediment loads from un-natural sources and improved transport efficiency in the upper watershed. In the Big Quilcene, aggradation is attributed primarily to high sediment transport from road and slope failures in the upper watershed. In addition, of the 87 culverts located in the drainage, 60 percent are in sediment source areas reaches. Culverts are concentrated in the unstable reach between RM 6 and 10 (ITWW et al. 1997). The river bed has aggraded

7 feet between RM 0 and 0.5, and 2 feet between RM 0.5 and 1.0. However, since 1993 the river bed in this reach has not appreciably aggraded, based on cross-section surveys conducted by Jefferson County Conservation District. Since the levee on the left (north) bank was removed in 1995 channel sinuosity has started to re-form and pool complexes are developing in this reach (Latham, Jefferson County Conservation District personal communication).

Riparian Zone

The first segment is tidally influenced, and bordered by marsh or agricultural land. The riparian forest is mostly mature, deciduous species in Segment 2, developed as residential in the lower reach, and forested along the upper reach. The riparian zone of Segment 3 has young conifers growing on the right bank, and the left bank is cleared, agricultural land.

Overall, the riparian zone is in poor condition (Bernthal et al. 1999). Almost half (45 percent) of the riparian zone below RM 2.8 is less than 66 feet wide. Existing forest is typically young (44 percent less than 12" dbh), dominated by deciduous species, so potential recruitment of LWD is poor to moderate in most reaches. The loss of riparian forest has reduced LWD, which has reduced habitat diversity and the natural tendency of the channel to meander. The banks are made more susceptible to erosion, which creates a wider, shallower channel. The sediment filtering effect of the riparian zone is reduced, overbank velocity is increased, and channel switching occurs more frequently (Williams et al. 1995).

Sub-estuarine zone

Dikes that were built along the lower river and south of the river mouth have isolated estuarine sloughs. The river mouth has extended 1700 ft into the Bay due to dredging and diking, which obstructs 21 percent of original delta (125 acre). The delta was also filled at the southeast corner, eliminating 3 percent or the original area, and a further 2 percent was excavated to create a waterfowl pond. At 0.45 mile-long piledike was also installed along the southern edge of the delta (Ames et al. 2000).

8.4.2.2 *Penny Creek*

The condition of the entire stream (7.15 stream miles) was assessed in the Big Quilcene WA. The drainage comprises 4,219 acres (6.6 square miles). Generally a low gradient stream, with many beaver ponds in upper segments, Penny Creek drops steeply in the lower reach before entering the Big Quilcene River at RM 2.8. The WA found evidence (Washington Department of Game surveys in the late 1970's) of a healthy population of coastal cutthroat trout in the lower reaches. The upper reaches were not surveyed, but are likely productive for cutthroat. Anadromous fish may have used Penny Creek, since there are no natural barriers, but no historical information exists. At its lower end the stream is diverted to the QNFH through a 250-foot culvert, which is screened to prevent passage. This culvert is perched two feet at the lower end, a barrier in itself at low flow. The intentional block was created to prevent fish access into Penny Creek, to assure that the hatchery water supply would be free of disease.

The WA did not include field assessment of habitat quality, so ratings were based on existing data. Reconnaissance in 1994 confirmed that abundant low gradient pool habitat, complex channels, and side channels were present. LWD was not abundant. The drainage burned in the 1920's, and was salvage logged in the 1930's. The riparian zone is dominated by alder, with a conifer understory that will recover as alder senesces. A possible barrier is created by the culvert at the 3057 road crossing. Overall, the productive capacity of the stream was rated high. The WA recommended that re-establishment of passage for anadromous fish should be investigated. It disagreed with conclusion of the Dungeness-Quilcene Pilot Project analysis (Jamestown S'Klallam Tribe 1994) which assessed its productive potential

to be low. Water supply issues for the QNFH may need to be addressed in order to re-establish passage that would make the 4.4 miles of anadromous habitat available.

8.4.2.3 *Townsend Creek*

Townsend Creek is a small stream that does not form and maintain deep pools except at some locations in the high gradient reach, and where LWD is present in upper segments. Flow is normally insufficient to transport LWD. The WA assessed the condition of 4.8 miles of stream above the confluence with the Big Quilcene River at RM 18.25. They found evidence of a self-sustaining resident cutthroat trout population above the falls in Segment 2. Brook trout were stocked into the upper reaches in 1963 to 1972, but were not found in 1992 surveys. Additional habitat surveys also were conducted in 1972, 1978, and 1992 (cited in BQWAT 1994). LWD recruitment was found to be low due to timber harvest in the riparian zone above Segment 5. LWD was removed from Segments 6 and 7 in the early 1980's. Recruitment potential for LWD is higher in Segment 5 and below, but this reach is influenced by sediment input from higher reaches.

8.4.2.4 *Spencer Creek*

Spencer Creek is an independent stream that drains a watershed of 3.29 square miles, and enters Quilcene Bay one mile south of the Big Quilcene River. The WA assessed the condition of five segments (2.5 miles). Segments 1 and 2 are low gradient deposition reaches which support spawning and rearing for chum salmon, coho salmon, and coastal cutthroat trout. Anadromous access is blocked by cascades below Segment 4. Segments 5 through 9 support a self-sustaining cutthroat population, of unknown origin. Habitat surveys have not been done, so the Watershed Analysis ratings were based on interviews with biologists and the channel morphology assessment. In the lower two segments, spawning habitat is influenced by sediment load. Lack of LWD limits and pool size and quality.

8.4.2.5 *Marple Creek and Jackson Creek*

Marple Creek and its tributaries drain a 3.28 square mile watershed south of the Big Quilcene River. Coho salmon, fall chum salmon, and anadromous cutthroat utilize the lower 0.9 miles. Juvenile coho salmon have been collected higher in the drainage (Segments 5 and 6). The land adjacent to the lower 0.9 miles of Marple Creek and lower 0.3 miles of Jackson Creek is privately owned. Water diversion structures in the upper reaches of Jackson Creek may block migration of resident trout. The Big Quilcine WA assessed the condition of 6 segments in the lower drainage (2.75 miles) plus another 0.8 miles above Segment 6. In Marple Creek the WA assessed habitat conditions of two segments totaling 3.5 miles.

Habitat for anadromous species in the lower reaches is influenced by the naturally high frequency of mass wasting and resulting high sediment loading. However, input of coniferous LWD into reaches above Segment 2 assists in sorting and retaining sediment creating buffering effects on the lower reaches. LWD has been removed from the lower reaches for flood control, and the riparian zone has been partially cleared and developed. Pool habitat is rated fair.

8.4.3 Historic Habitat Conditions

Historically, stream conditions in the Big Quilcene system was controlled by natural flood and mass wasting events. Those following catastrophic fires had the greatest and longest lasting effects. Between fires, LWD and sediment were transported and sorted, reaching dynamic equilibrium as riparian vegetation and forest canopies were re-established. It is apparent that biological systems endured cyclic

and variable productivity. At the time of settlement the basin was recovering from the catastrophic 1701 fire. Through the 1930's forestry was limited to low elevations, close to rail and marine transport. Surveys conducted in the 1880's showed diked channels in the lower river, indicating that natural functions at the delta – estuarine interface have been disrupted for at least 100 years. Timber harvest and roads increased rapidly in the 1940's, with peaks in the 1960's and 1980's. The WA concluded that the recent volume of sediment input, as a result of timber harvest and roads, was not likely higher than seen historically after large fires. The steep and confined channels in the upper drainage transfer sediment quickly downstream, with consequent marked effects in the lowest reaches of the river (BQWAT 1994).

In the mid-1950's the riparian zone forest below RM 2.8 was still intact, and the channel a single thread with abundant pools and LWD (Johnson, WDFW personal communication cited in Bernthal et al. 1999). Since the early 1970's the channel has aggraded, widened, and become unstable. Forest on the left (north) bank has been harvested or lost due to channel migration. Dikes built in the 1970's had an immediate de-stabilizing effect on the channel.

Comparison of aerial photos taken in 1947 and 1962 show major changes in the lower river, e.g. much larger gravel bars, and a wider channel, below the highway 101 bridge. Intensive timber harvest between 1953 and 1962, and the associated road construction, apparently caused this aggradation (Geomax 1989). Photographs taken in 1973 showed that meanders formerly present in the lower river were gone, apparently due to dikes construction.

The WDFW permitted 24 hydromodifications in the lower 4 miles of the Big Quilcene between 1989 and 1995 (ITWW et al. 1997). These included 11 dredging projects, 3 LWD removal projects, and 10 bank protection projects. In the lower 2 miles, 1.1 miles of mainstem channel have been diked or armored. Between RM 2 and 4, 0.6 miles have been modified, so 41 percent of the lower 4 miles have been diked or armored. In December 1993, illegal dike construction destroyed 29 percent of the summer chum salmon redds (Uehara 1994).

Anadromous fish habitat in the lower Big Quilcene valley is estimated to include 7.4 mile of large tributary stream channel, 5.1 miles of small tributary channel, 15.1 acres of perennial wetland, and 41.8 acres of seasonal wetland (ITWW et al. 1997). Permanently lost habitat includes 1.7 miles of small tributary channel, 1.2 miles of side channel slough, 0.8 miles of distributary slough, and 22.2 acres of wetland which is isolated from the mainstem. No side channel or distributary slough habitat remains in the anadromous zone. A General Land Office Survey map from 1859 showed a large wetland near the town of Quilcene. A small tributary connecting this wetland to the Big Quilcene channel no longer exists. A War Department topographic map from 1936 shows a 0.5 mile side channel at RM 1.5. This channel was still apparent on 1957 aerial photos. The 1936 map also showed a 0.8 mile distributary slough exiting the main channel east of Quilcene, and flowing northeast to Quilcene Bay. The 1957 aerial photos show several side channels totaling 0.5 miles near RM 1.0.

8.4.4 Limiting Factors for Chum Salmon

Decline of summer chum salmon cannot be attributed to a single factor. Co-managers and other investigators have not rated the significance of the effects of the different aspects of habitat degradation.

Upstream migration of adult salmon, particularly summer chum salmon that migrate in August and September, is inhibited at low flow due to channel aggradation, channel instability, and the low quantity of LWD which limits pool formation. Water diversion from the upper watershed may exacerbate low flow, but recent operating agreements have minimized withdrawal during the base flow season.

Lack of LWD is constraining the formation and maintenance of pools that are necessary for pre-spawning holding areas for returning adult salmon. Frequent dredging of the channel and dikes below RM 0.8 have isolated the few side channels that still exist, which prevents outmigrant fry from reaching the estuary before moving into Quilcene Bay. At this very early life stage, this rapid exposure to deep, open water leaves fry highly vulnerable to predation. The impact of degraded subestuarine habitat on migratory life stage is rated high (Ames et al. 2000). However, there is some potential for recovery of natural channel function, if dikes are removed or set back. Jefferson County removed a portion of the dike below RM 0.5 in 1995, and further removal is warranted (Frederick 1995).

Levee construction has disturbed spawning areas, and has prevented scouring and clearing of secondary channels (Williams et al. 1995). Chum salmon spawn in stable and uniform gravel riffles, most often found in the main channel but also in side and distributary channels. Spawning areas are affected by sedimentation and scour during the incubation season. Alterations have tended to make riffles shallower and wider, less suitable for spawning and incubation.

8.4.5 Restoration Activities

Restoration projects in this sub-basin include measures to address stream aggradation, as well as other habitat restoration activities such as barrier removal and riparian vegetation plantings. These restoration activities are described in the following sections.

8.4.5.1 *Stream Aggradation*

Gravel traps are intended to induce downstream scour and lower streambed elevation, in order to reduce flood risk. However, traps only achieve their desired purpose to the extent that they trap larger bedload material. Scouring downstream may result only for a few hundred feet downstream, and effect small reduction in bed elevation (Collins and Associates 1993). Potential unwanted effects on fish habitat include channel downcutting through intact gravel bars, upstream and downstream of the trap. This could result in a wider, shallower, low-flow channel, perhaps less suitable for summer chum salmon passage and spawning.

Nevertheless, the first two gravel traps were excavated in August 1993, removing 500 and 800 cubic yards, respectively. Monitoring by QNFH staff did not observe negative effects on spawning chum salmon and coho salmon and there was no indication of head cutting. The traps were filled by the first major storm in December 1993. Further excavation was recommended, and FWS suggested that ingress and egress channels for fish not be built in order to reduce chance for stranding (Cook 2000).

The Fish and Wildlife Service (Frederick 1995) found that gravel traps on the Shahda property (RM 0.3) would benefit fish habitat and agreed to provide shared funding. FWS recommended that the trap excavation contract be extended to include removal of 800 feet of levee, to release the channel, and enable side channel development and re-establishment of riparian vegetation. The traps were found to stabilize spawning habitat by minimizing scour and trapping excess sediment. FWS declined to fund a second gravel trap at Rogers Street, because of perceived lower or questionable benefits to salmon.

Two gravel traps were excavated in October 1995, removing approximately 2,000 cubic yards of material. They were excavated annually in September or October, for the next four years. Between 1630 and 2400 cubic yards of material was removed each year, at a cost of approximately $13,000 per year. Levee removal was increased to 800 feet (Jefferson County Conservation District, personal communication).

Jefferson County Public Works completed a floodplain management plan in cooperation with the tribes, WDFW, and the Quilcene community. In addition to gravel traps, it included a menu of flood control

strategies, including construction of additional overflow channels, removal or setback of dikes in the lower river and estuary, and floodplain acquisition.

8.4.5.2 *Completed and Planned Restoration Projects*

Restoration projects that have been completed in this sub-basin are shown in Table 8-8.

Table 8-8. Summary of Completed Restoration Projects in the Big Quilcene Sub-basin

Stream	Date	Restoration Type	Description
Big Quilcene River	8/30/1994	Salmon Habitat Restoration	Removed 800 ft of dike removal –County property
Big Quilcene River		Salmon Habitat Restoration	Purchased 30 acres of land along the lower reaches of the river and removed all structures
Big Quilcene River	10/31/1995	Streambank Stabilization	Hiddendale bank stabilization
Big Quilcene River	12/30/1995	Streambank Stabilization	Rose streambank protection
Big Quilcene River	12/30/1995	Streambank Stabilization	USF and WS hatchery bank protection
Big Quilcene River	12/30/1995	Riparian Planting	Cory riparian planting
Big Quilcene River	12/30/1995	Salmon Habitat Restoration	Cory stream restoration project
Indian George Creek		Culvert Replacement	Replaced undersized culvert at Longer Rd.
Indian George Creek	1998	Erosion Control	Stabilized eroding banks at RM 0.8
Indian George Creek	12/31/1999	Salmon Habitat Restoration	Indian George Creek stream improvements
Cemetery Drain	12/31/1992	Riparian Fencing	McGuire fence

Source: JCCD

Restoration projects planned by JCCD to be constructed in the summer of 2000 or later in the Big Quilcene sub-basin include:

- Stabilize tow of high eroding bank with LWD on the Big Quilcene River at RM 1.2 to 1.3.
- Add additional LWD to project done in 1999 in Indian George Creek at RM 0.0 to 0.3.

8.5 INSTREAM FLOW

Caldwell (1999) presents a series of predicted habitat/flow relationships developed using the IFIM method for the Big Quilcene River based on information from a study site at RM 1.1. Species and lifestages considered included coho salmon, chinook salmon, chum salmon and steelhead spawning, and steelhead and chinook salmon juvenile rearing (see Table 6-2). These optimum flow/habitat predictions ranged from a low of 40 cubic feet per second (cfs) for steelhead juvenile rearing to a high of 180 cfs for chum salmon spawning. These modeling results can be used, along with existing or synthesized hydrologic records, to develop a series of instream flow recommendations based on the needs of those salmonid species, as well as other physical and water quality considerations (such as in-migration and out-migration flow needs, and water temperatures).

Ecology and WDFW (1999) also present toe-width study results for Spencer Creek (RM 0.0). Species and lifestages considered included chinook salmon, coho salmon, chum salmon and steelhead spawning, and steelhead and salmonid juvenile rearing (see Table 6-1). These study results ranged from a low of 4.6 cfs for salmonid juvenile rearing to a high of 27.8 for chinook salmon and chum salmon spawning. These

results can be used to develop instream flow recommendations for Spencer Creek. Results were not developed for Marple Creek because no streamflow was present.

Hiss (1993) presented optimum instream flows for the Big Quilcene River, and Penny Creek (see Table 6-3). Species and lifestages considered were chinook salmon, chum salmon and steelhead spawning, and steelhead rearing. The optimum flow for the Big Quilcene River ranged from a low of 50 cfs for steelhead rearing to a high of 198 cfs for chinook salmon and chum salmon spawning. The optimum flow for Penny Creek ranged from a low of 13 cfs for steelhead juvenile rearing to a high of 55 cfs for steelhead spawning. (Penny Creek is not managed for instream fish production, but for hatchery water supply (Boomer 1994).

At this time, these two sets of results for the Big Quilcene River cannot be directly compared. Caldwell (1999) presents a series of study results that have not yet been developed into instream flow recommendations, while Hiss (1993) presents only theoretically optimum flows. Orsborn and Orsborn (2000) are in the process of developing estimates of flood, average annual and low flow characteristics of the Big Quilcene River near its mouth.

8.6 FUTURE GROWTH AND POTENTIAL IMPACTS

8.6.1 Big Quilcene Sub-basin Population Growth

In 1996, the Big Quilcene sub-basin had 1,299 residents (Jefferson County 2000). Big Quilcene sub-basin population growth over the next 20 years is estimated at 644 residents (Jefferson County 1998). Based on existing zoning (refer to Exhibit 1), the population growth will most likely occur in the town of Quilcene, along the lower two miles of the Big Quilcene River and in shoreline areas near Whitney Point.

8.6.2 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity

At the time of this writing, the only data available to characterize or predict future changes in land use were the population projections presented in Chapter 1. For several types of land use (e.g. logging and agriculture), the lack of specific information regarding anticipated future changes makes it impossible to predict related impacts to groundwater and surface-water quantities. General discussion of the relationships between these particular land uses, streamflow and groundwater recharge is included in Chapter 4. However, it should be noted that the impacts of such land uses may be highly dependent on particular site characteristics.

The population projections and zoning patterns discussed above, however, can be used to qualitatively predict changes in patterns of residential and associated commercial land use. Increased population requires increased paved surfaces for homes, driveways, roads, and commercial infrastructure. In the Big Quilcene sub-basin, most of the projected growth is likely to occur in rural residential areas, and thus dense areas of paved surfaces are not expected. As indicated in Chapter 4, little direct data are available regarding the effects of paving on groundwater recharge at typical rural residential densities. While the effects of increased paving in rural residential areas are not expected to be substantial, some reduction in recharge may be associated with conversion of forested lands to meadows and lawns. Where growth occurs in the rural village center of Quilcene, increases in impervious area may cause locally increased runoff and reduced recharge unless appropriate stormwater management measures are taken. The effect of population increase on groundwater and surface water withdrawals is presented in Section 8.6 of this report.

8.6.3 Potential Impacts of Growth in the Big Quilcene Sub-basin on Water Demand

Population in the Big Quilcene sub-basin is expected to increase by 50 percent between 1996 and 2016. Assuming that an average residence contains 2.2 people and uses 250 gpd, the projected increase of 644 people will cause an increased water demand of approximately 82 af/yr. Groundwater is currently the principal source of residential supply for most of the sub-basin, and is predominantly withdrawn by small public water systems and exempt wells. Additional demand will likely be satisfied by similar sources, although the residents of Quilcene have considered installation of a centralized public water system. If additional demand is met with the groundwater resource, estimated current groundwater withdrawals (322 af/yr for residential, commercial and agricultural purposes) would increase by about 25 percent. The increased demand also represents about 0.8 percent of estimated groundwater recharge, with current groundwater withdrawals estimated at 3.1 percent. However, as discussed in Chapter 4, comparison of groundwater pumping with recharge cannot be reliably used as a direct indicator of groundwater availability.

Given the rural nature of the sub-basin, residential reliance on septic systems dictates that the consumptive portion of residential use is significantly less than the total residential groundwater withdrawal. Assuming that 87 percent of residential withdrawals are returned to the ground via septic infiltration (Solly et al. 1993), the actual increase in groundwater consumption would be on the order of 11 af/yr.

8.6.4 Potential Impacts of Growth on Habitat

The potential impacts of growth are difficult to predict with any precision due to the dynamic nature of salmon recovery programs, land use protection and restoration activities. The following discussion therefore focuses on those activities that have potential to have habitat impacts if not adequately mitigated.

The increase in population projected from 1996 to 2016 could increase domestic surface water use. Assuming this population growth occurs in the lower watershed, where hydraulic continuity potential is judged to be medium to high to high, additional groundwater withdrawal has potential to affect stream flow.

Low stream flow and aggradation is now cited as limiting access to and quality of summer chum salmon spawning habitat. Until the aggraded channel is naturally degraded, and channel complexity is increased, this access limitation will likely persist.

8.6.5 Conservation Options

Potential Conservation options that may be applicable for water users that divert from the Big Quilcene River or use groundwater in the Big Quilcene sub-basin are summarized below.

- Tiered Water Rate Structures
- Modification of Landscape Irrigation Practices
- Water Conservation in Water Supply Systems and Individual Homes
- Educational programs
- Water Re-Use
- Increased Storage, Either Through Surface Storage Or Aquifer Storage
- Water Conservancy Boards To Facilitate Water Rights Transfers
- Implement water conservation at Port Townsend Paper Company

8.7 DATA SYNTHESIS AND INTEGRATION

Concurrent issues in the Big Quilcene sub-basin are most concentrated in the lower watershed where most habitat impacts have been identified, and groundwater use is highest. By 2016, an estimated 644 residents are projected to be added to this sub-basin. Hydraulic continuity and higher groundwater use in the lower segment of the Big Quilcene River may have potential to increase existing habitat impacts.

The optimum instream flow for the Big Quilcene River should be understood in the context of management objectives for Hood Canal fisheries resources and recognition of competing uses for surface water and groundwater. First, it is unlikely that the requirements of chinook salmon are relevant to the setting of target flow. State and tribal co-managers will not, in the foreseeable future, manage chinook salmon production in this system. However, the habitat requirement of summer and fall chum salmon, coho salmon, and steelhead are of immediate relevance. It is important to recognize that optimum in-stream flows, based on IFIM or toe-width methodologies, estimate the flow level that provides the maximum area of suitable habitat for each species and life stage, without regard for the natural hydrograph or for the management objectives for the species in question. There is no simple, quantified relationship between fish production, for any species, and the area of suitable habitat. To the extent that other habitat limiting factors have been identified, there is may be greater emphasis on protection and restoration of riparian buffer zones, restoration of channel complexity and sinuosity (particularly in the lower Big Quilcene where dikes and armored banks constrain the channel), and reduction of sediment loading.

Spawning escapement goals are established for summer and fall chum salmon and coho salmon, but the area of spawning habitat to enable that number of adults to spawn successfully is known only approximately. After the eggs are deposited, their survival through various life stages until they emigrate to marine areas is determined by a very complex set of factors that include streamflow, temperature, prey production, competition, and predation. Streamflow cannot be used alone to accurately predict freshwater survival. Increasing streamflow during certain critical life history phases is a valid objective, but only in the context of measures to mitigate other habitat limiting factors.

Water quality does not currently appear to be a concern with respect to the quality of freshwater habitat, but non-point source fecal coliform contamination of shellfish beds will likely continue to be a concern as the sub-basin develops and harbor seals raft at the entrance to Quilcene Bay.

8.8 DATA QUALITY, DATA GAPS AND LIMITATIONS

In addition to the general data gaps identified for the entire WRIA, the following specific data gaps have been identified for the Big Quilcene sub-basin:

8.8.1 Water Quality

- Water quality data tends to be of limited scope and duration. Except for temperature and turbidity data collected by the City of Port Townsend, and monitoring of selected streams by the JCCD, on-going routine monitoring that generates data suitable for detection of trends is generally not available.

- The majority of water quality data for the Big Quilcene sub-basin is at least five years old, with majority of data approximately 10 years old. The age of this data limits the ability to assess whether current land use activities in the watershed are currently contributing to water quality problems.

- Elevated water temperature has not been identified as a water quality issue in this sub-basin. If temperature is determined to be an issue, then analysis of raw temperature data collected by Bahls (1995-97) and at the Quilcene National Fish Hatchery from the 1970s to present (prior to 1983 the temperature data are not computerized), should be considered to determine potential temperature trends.

8.8.2 Water Quantity

Water quantity data gaps have been identified for the entire WRIA and generally apply to the Big Quilcene sub-basin. The following additional definition of data gaps is based on consideration of currently existing data, and provides additional detail where possible:

- Hydrogeologic characterization is largely lacking in the lowlands of the Big Quilcene sub-basin. Conditions in the deltaic aquifer and the till covered areas immediately upstream could be better characterized through hydrogeologic cross-sections and water-level maps.

- Hydraulic continuity between the Big Quilcene River and the deltaic aquifer at the river mouth, as well as other upgradient aquifers, has not been well defined. Better understanding of hydraulic continuity will allow improved predictions of the impacts of additional groundwater development on stream baseflows.

- Recharge to bedrock areas could be better defined by based on baseflows from bedrock dominated portions of the sub-basin and consideration of snowmelt throughout the year.

- Quantities of groundwater flow from bedrock to adjacent unconsolidated sediments are unknown. Such estimation can only be achieved with extensive hydrogeologic characterization, including definition of aquifer occurrence, aquifer properties, and groundwater level gradients.

- Stream flow data is not available in this sub-basin except for the Big Quilcene River.

8.8.3 Habitat

- Hydrologic studies that would determine the extent to which existing and new groundwater withdrawal in the most densely populated lower basin may affect flow in the Big Quilcene River.

- Better quantify the relationship between streamflow and summer chum salmon spawning habitat quantity and quality.

- Studies to quantify bed scour in chum salmon and coho salmon spawning areas.

- Monitor the adequacy or existing measures and programs to abate mass wasting on Forest Service land in the upper watershed.

- Catalog the small unnamed streams that have potential to support cutthroat trout and possibly other salmonids.

8.8.4 In-Stream Flow

There are no significant data gaps with respect to in-stream flow in this sub-basin with the exception of certainty of in-stream flow levels on the Big Quilcene River. The WRIA 17 Planning Unit is currently working with Ecology to determine how to potentially address this uncertainty. Diversions on the Big

Quilcene River are managed to comply with a voluntary instream flow arrangement, which restricts diversion during low-flow periods. For other streams there is enough information to develop instream flow recommendations and to proceed with the setting of instream flows in most of the larger streams in the basin.

9. LITTLE QUILCENE SUB-BASIN

9.1 SUB-BASIN DESCRIPTION

The Little Quilcene River basin of approximately 40 square miles includes 12.2 miles of mainstem channel, and 81.2 miles of tributary streams (Figure 9-1). The upper watershed down to RM 6.6 is within the Olympic National Forest and is steeply dissected with high gradient, confined stream channels. The lower seven miles runs through glacial sediments, siltstone and sandstone. This lower valley, including the floodplain, has been developed for domestic and agricultural use, and timber harvest. Along the Little Quilcene River, below RM 3.0, 60 percent of the riparian zone is developed (33 percent in agricultural use, 11 percent as roads or dikes, 6 percent in commercial forestry). The lower 0.8 miles have been diked and the banks armored to protect property in the floodplain. In the Donovan Creek watershed, 14 percent of the land has been developed for agriculture, and 4 percent for rural residential use.

9.1.1 Surface Water Features

The Little Quilcene River originates on the east slopes of the Olympic Mountains within the Olympic National Forest. The headwaters of the Little Quilcene River originate above 4,400 feet on the north slopes of Mt. Townsend and its runoff is derived from both rainfall and snowmelt. The Little Quilcene River discharges to Quilcene Bay approximately one mile north of the mouth of the Big Quilcene. The largest tributaries in the Little Quilcene River sub-basin are Howe Creek, Ripley Creek and Leland Creek. Other streams include Donovan Creek and Jakeway Creek which drain directly to Quilcene Bay. There are four lakes located in the sub-basin. The largest of which is Lake Leland that feeds Leland Creek. Primary freshwater features in this sub-basin are summarized in Table 9-1.

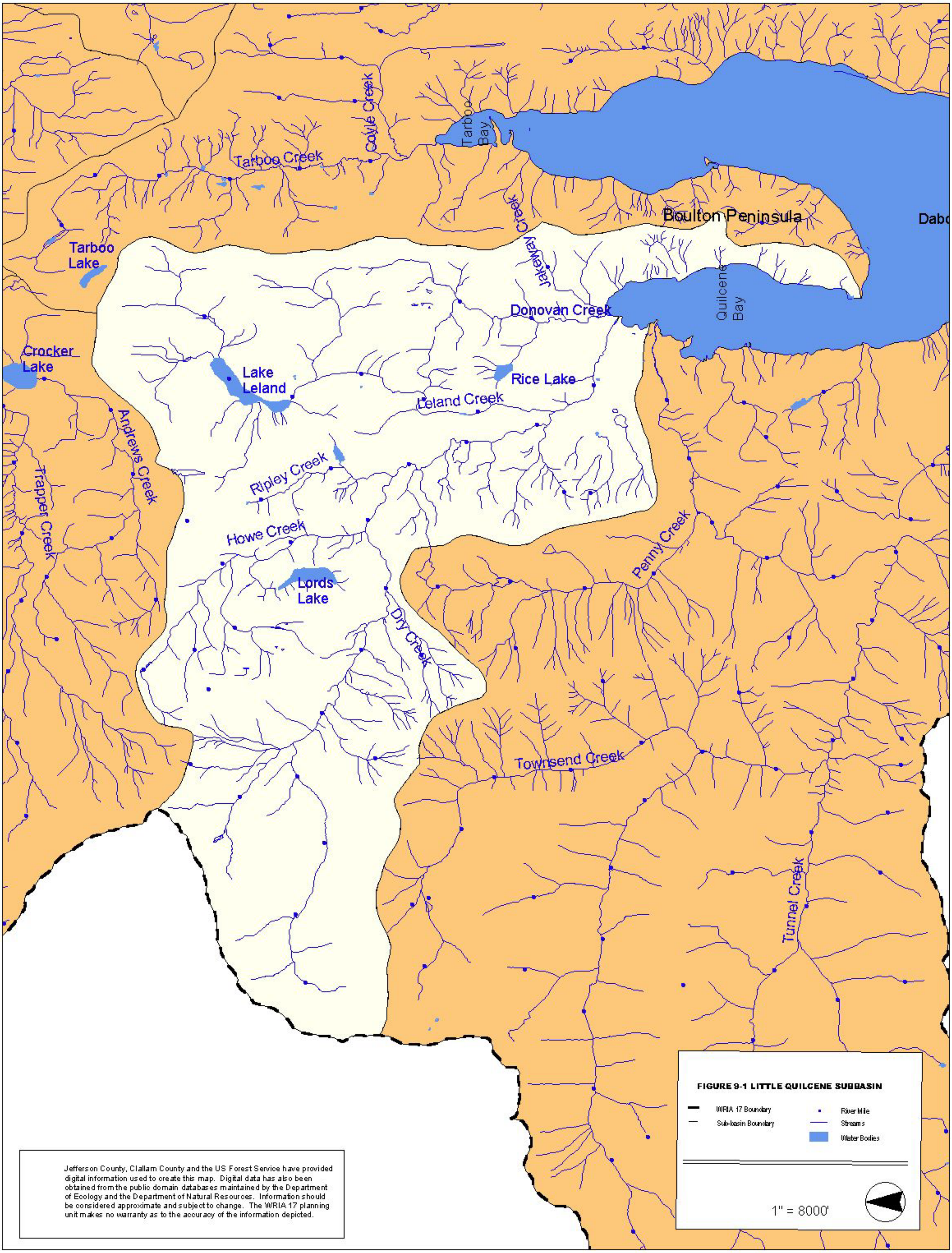
Table 9-1. Fresh Water Features in the Little Quilcene Sub-basin

Main Water Feature	Tributary	Confluence	Ecology Class
Little Quilcene River			Class AA
	Leland Creek	RM 1.7	Class AA
	Ripley Creek	RM 4.35	Class AA
	Howe Creek	RM 5.2	Class AA
	Dry Creek	RM 6.1	Class AA
	Deadfall Creek	RM 8.55	Class AA
Donovan Creek			Class AA

Source: Williams et al. (1975)

9.1.2 Groundwater Features

Hydrogeologic characterization in the Little Quilcene sub-basin is limited to existing maps of surficial geology, several generalized geologic cross-sections (PGG and EES 1994; Grimstad and Carson 1981), limited discussion of potential well yields (ibid) and mapping of miscellaneous groundwater levels (Grimstad and Carson 1981). Exhibit 17 shows the generalized surficial geology for the area. The groundwater flow system for the upper reaches of the watershed are dominated by bedrock geology. Whereas the sedimentary bedrock north of Quilcene Bay tends to produce little water, volcanic bedrock in the Olympic foothills can provide yields suitable for single family use (Gimstad and Carson 1981). In the lower portions of the sub-basin recessional outwash and alluvium are extensively present near the mouth of the Little Quilcene River, Leland, Donavan and Jakeway Creeks. Similar to the Big Quilcene sub-basin, these deposits may comprise the principal aquifer for many of the domestic wells in this area.


Tarboo Creek
Coyle Creek
Tarboo Bay
Boulton Peninsula
Tarboo Lake
Jakeway Creek
Quilcene Bay
Donovan Creek
Crocker Lake
Lake Leland
Rice Lake
Leland Creek
Andrews Creek
Trapper Creek
Ripley Creek
Howe Creek
Penny Creek
Lords Lake
Dry Creek
Townsend Creek
Tunnel Creek
FIGURE 9-1 LITTLE QUILCENE SUBBASIN
WRIA 17 Boundary
Sub-basin Boundary
River Mile
Streams
Water Bodies
1" = 8000'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.

Potential well yields from these sediments are variable (PGG and EES 1994; Grimstad and Carson 1981). The upper catchments of Ripley and Leland creeks are largely covered by till, which likely overlies bedrock but may also overly other glacial sediments. Exhibit 17 shows that the Bolton Peninsula is till covered along its axis, but shows broad exposures of underlying principal aquifer materials to either side. Hydrogeologic characterization of this area has not been performed to determine the nature of the principal aquifer beneath the till.

9.1.3 Land Use

Land use in the Little Quilcene sub-basin includes approximately 9,872 acres (44 percent of the total watershed) within the Olympic National Forest, and another 8,224 acres (36 percent of the total watershed) is zoned for privately-held forest land. Development in the Little Quilcene River watershed is generally limited to the lower portions of the watershed near the town of Quilcene. There are 6,147 acres of rural residential zoning in the Little Quilcene watershed, 383 acres of agriculture, and 57 acres of rural village and industrially zoned lands. The predominant residential zoning in this watershed (3,123 acres) is one residence per 5 acres. Existing land use in this sub-basin is shown in Table 9-2.

Table 9-2. Little Quilcene Sub-basin Land Use

Description	No. of Parcels	Acres	% of Total
Rural Residential (1:5)	951	3,123	11.4%
Rural Residential (1:10)	13	92	0.3%
Rural Residential (1:20)	220	2,932	10.7%
Parks, Preserves, Recreation	5	16	0.1%
Olympic National Forest	13	9,872	36.0%
Rural Forest	78	2,243	8.2%
Commercial Forest	136	4,726	17.2%
Inholding Forest	33	1,255	4.6%
Commercial Agriculture	43	383	1.4%
Rural Village Centers (Hadlock, Brinnon, Quilcene)	57	30	0.1%
Light Industrial Zone (Quilcene)	3	21	0.1%
Tidelands	88	231	0.8%
Roads and Right of Way	118	307	1.1%
Totals	**1,758**	**27,424**	**100.0%**

Source: Jefferson County (2000) and Clallam County GIS. Parcel data is for Jefferson County only.

9.2 WATER QUALITY

9.2.1 Surface Water Quality

Freshwater quality data available for this sub-basin is summarized in Table 9-3. In general, temperature, DO, and FC have not exceeded state water quality standards for the Little Quilcene River based on studies by Gately in 1991, and 1992-1993, and data collected by the JCCD (2000). Leland, Donovan, and Jakeway Creeks have exceeded state water quality standards for one or more parameters.

Table 9-3. Water Quality Data Available for the Little Quilcene Sub-basin

Survey Areas	Parameters					Years Sampled	No. of Sample Locations	Reference
	Temp	DO	Cond	pH	Turb			
Little Quilcene	p					1991	2	Gately (1992)
Leland	p					1991	3	Gately (1992)
Donovan	p					1991	2	Gately (1992)
Little Quilcene	p	p			p	1992-1993	1	Gately (1993b)
Donovan	p	**X**			p	1992-1993	1	Gately (1993b)
Leland	**X**					1986 - 1987	3	JCCD (2000)
Donovan	**X**	**X**	p	**X**	**X**	1986 - 2000	6	JCCD (2000)
Little Quilcene	p	p				1986 - 1989	3	JCCD (2000)
Jakeway Creek	**X**	**X**	p	**X**	p	1988,89 95,96	9	JCCD (2000)

X = water quality was exceeded for at least one sample

p = no water quality criteria was exceeded.

Data from FC studies in Little Quilcene, Leland, and Donovan Creeks from 1986-2000 are summarized in Table 9-4. In general, higher FC concentrations in Donovan Creek were located in the lower watershed where livestock was more prevalent. Surface water FC data from stations DV1 and DV2 from Donovan Creek are shown in Figure 9-2. Sampling stations are shown in Exhibit 3.

Table 9-4. Summary of Little Quilcene Sub-basin Fecal Coliform Monitoring Data

Stream	Station	Monitoring Year FC GMV (FC/100mL)			
		1986-1989[a]	1991[b]	1992-1993[c]	1986 – 2000[d]
Little Quilcene	LQ1	9.5			
Little Quilcene	LQ 2	7.1	8		4
Little Quilcene	LQ 3	18	1	10.3	11
Leland Creek	LL 0	15	0		
Leland Creek	LL 1	19	2		10
Leland Creek	LL2				4
Leland Creek	LL 3	13	17		10
Donovan Creek	DV 1	17	8		8[e]
Donovan Creek	DV 2	**188**	**1,700**	**41.2**	**81**[f]

Bold = Standard exceeded.

Source:

a: Rubida and Calambokidis (1990)

b: Gately (1992); based on one sample

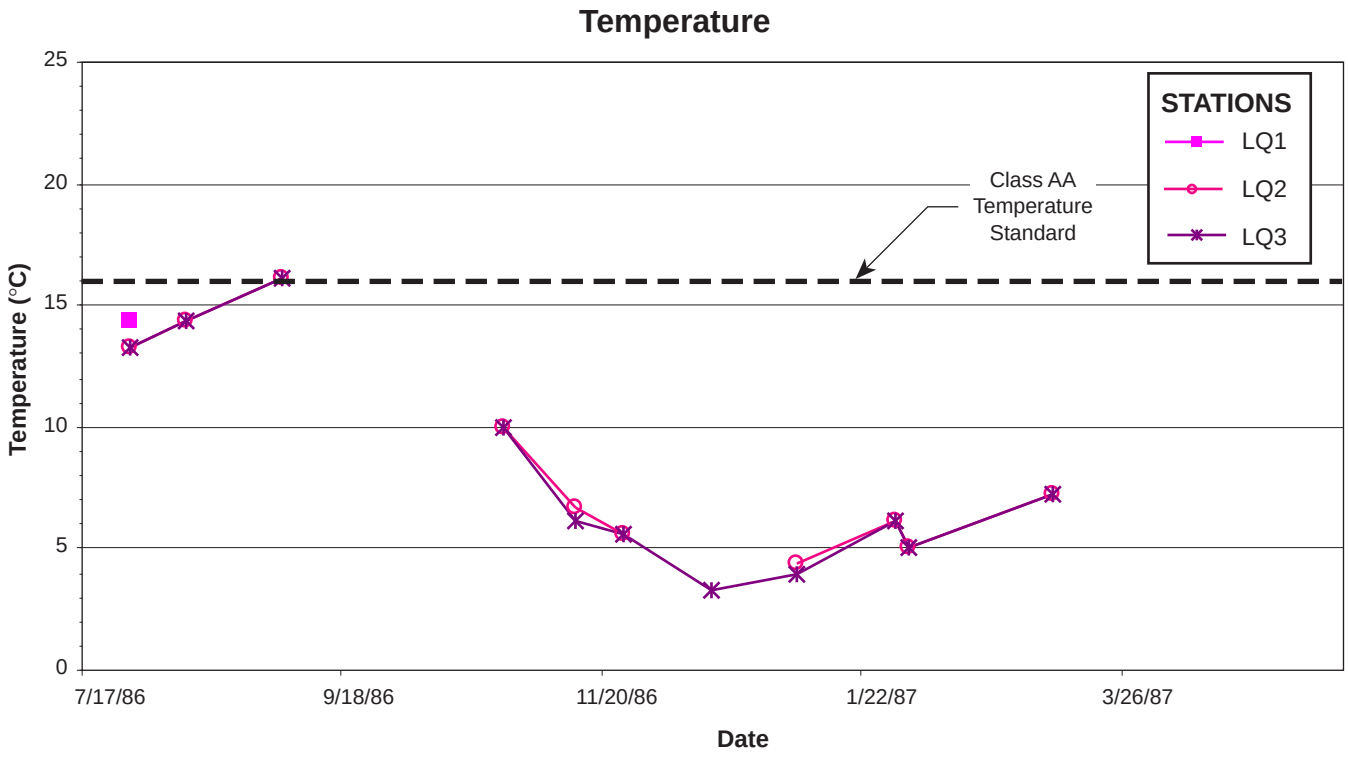
c: Gately (1993b)

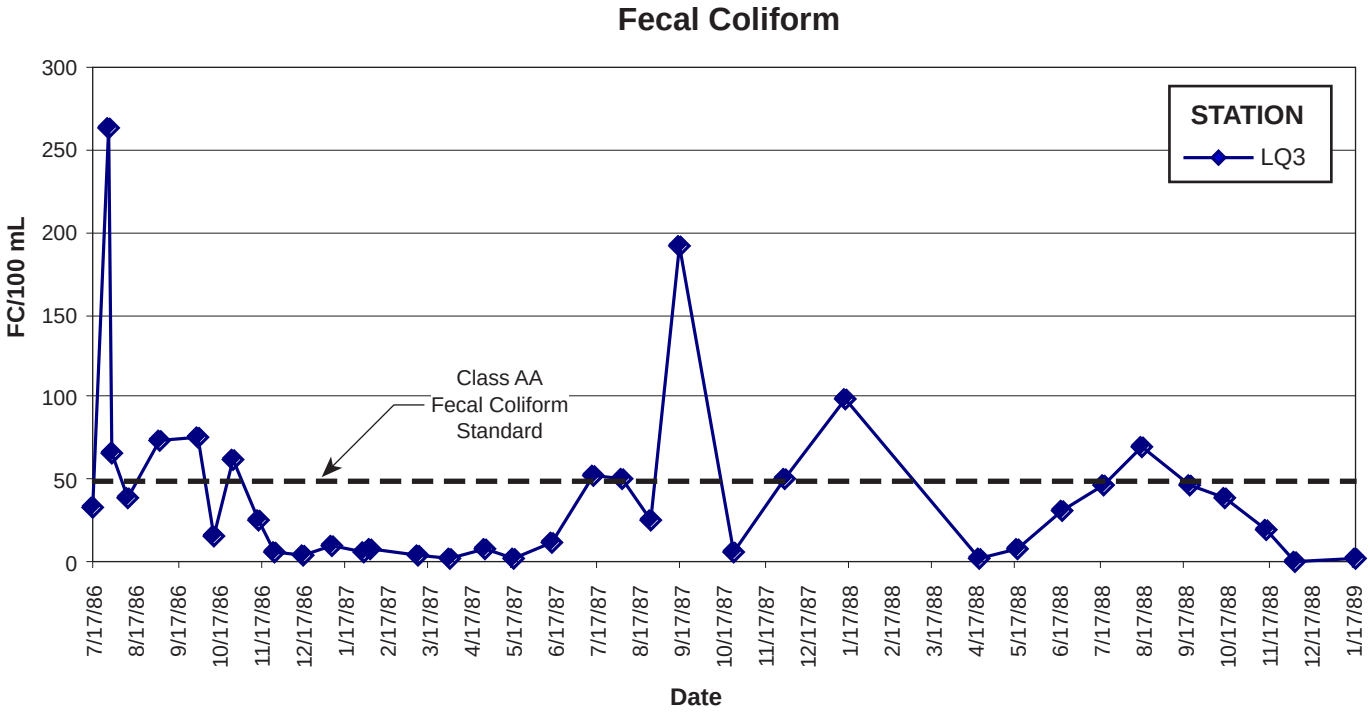
d: JCCD data base (2000)

e: DV/1.5 and DV/1.9 combined

f: DV/0.1, DV/0.4, and DV/0.5 combined

The JCCD database included water quality data from Little Quilcene sub-basin, and is summarized in Table 9-5. Temperature, pH, FC, and DO exceeded the state water quality standards at least once in each stream. Temperature recorded between 1986 and 1987 in Leland Creek shows that temperatures are in compliance with state water quality standards except for station LL3, which had one temperature above state water quality standards (16.7 C on 9/3/86). Donovan Creek exceeded state water quality standards for at least one parameter at all three locations. Location identifications in the JCCD database were listed by old and new station ID, with the new station ID corresponding to RM (labeled in parentheses in Table





Source: JCCD

Figure 9-2
Temperature and Fecal Coliform in Little Quilcene River (LQ3), July 1986 – January 1989

9-5). One old station (DV2) had two different new station IDs and were tabulated separately (DV2/DV0.1 and DV2/DV0.4).

Table 9-5. Water Quality Results for Streams in the Little Quilcene Sub-basin (JCCD 2000)

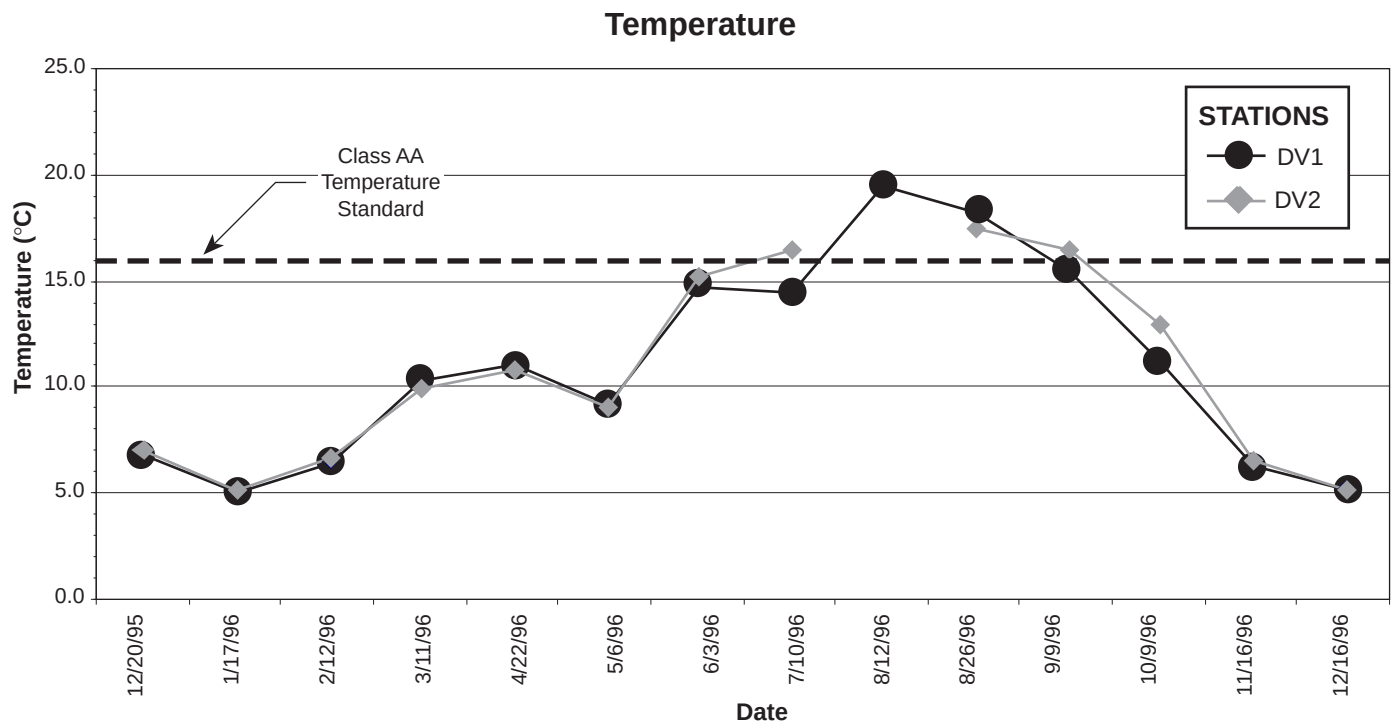
Area	Site	Date Sampled	Temp (C)	Cond (µmhos/cm)	pH	DO (mg/L)	FC GMV (FC/ 100 mL)	Turb (NTU)
Class AA Standard			<16.0	NA	6.5 - 8.5	>9.5	Geo Mean <50 and <10% >100	
Leland Creek	LL1	7/28/86	14.4					
	LL2	7/28/86	13.9					
	LL3	7/86 – 3/87	2.8 – **16.7**					
Donovan Creek	DV1 (DV/0.1)	12/95 – 12/96	5 – **19.5**	142 - 4640	6.7 – 7.5	**8.2** – 12.5	**78**	6.3 - 24
	DV2 (DV/0.1)	11/92 – 9/93	7.1 – 15.8	298 - 2320	6.9 – 7.1	**7.6** – 11.1	**100**	6.8 - 30
	DV2 (DV/0.4)	12/95 – 12/96	5.1 – **17.5**	61 - 194	**6.3** – 7.4	**7.3** –12.0	**67**	5.0 - 31
	DV2u (DV/0.5	12/92 – 12/93	0.1 – 8.2	78 - 200	6.5 – 7.3	**7.8** – 11.8	43	6.0 - 125
Little Quilcene River	LQ1	7/86 – 5/87	14				3.6	
	LQ2	7/86 – 5/87	4.4 – **16.1**				3.5	
	LQ3	7/86 – 1/89	3.3 – **16.1**				11	
Jakeway Creek	JK/0.0	12/95 – 12/96	5.2 – **18.6**	76 – 170	7.1 – 8.1	**7.8** – 12	**85**	2.8 – 21
	JK/0.1	12/95 – 12/96	5.2 – **25.4**	68 – 155	6.8 – 8.0	**7.8** – 12.3	**62**	2.1 – 17
	JK/0.2	6/95 – 12/96	5.5 – **24.9**	92 – 157	7.2 – **8.6**	**7.3** – 11.6	**180**	4.1 – **30**
	JK/0.4	12/95 – 12/96	5.7 – **17.2**	69 - 157	7.0 – 7.8	**8.4** – 12.9	15	2.9 - 19

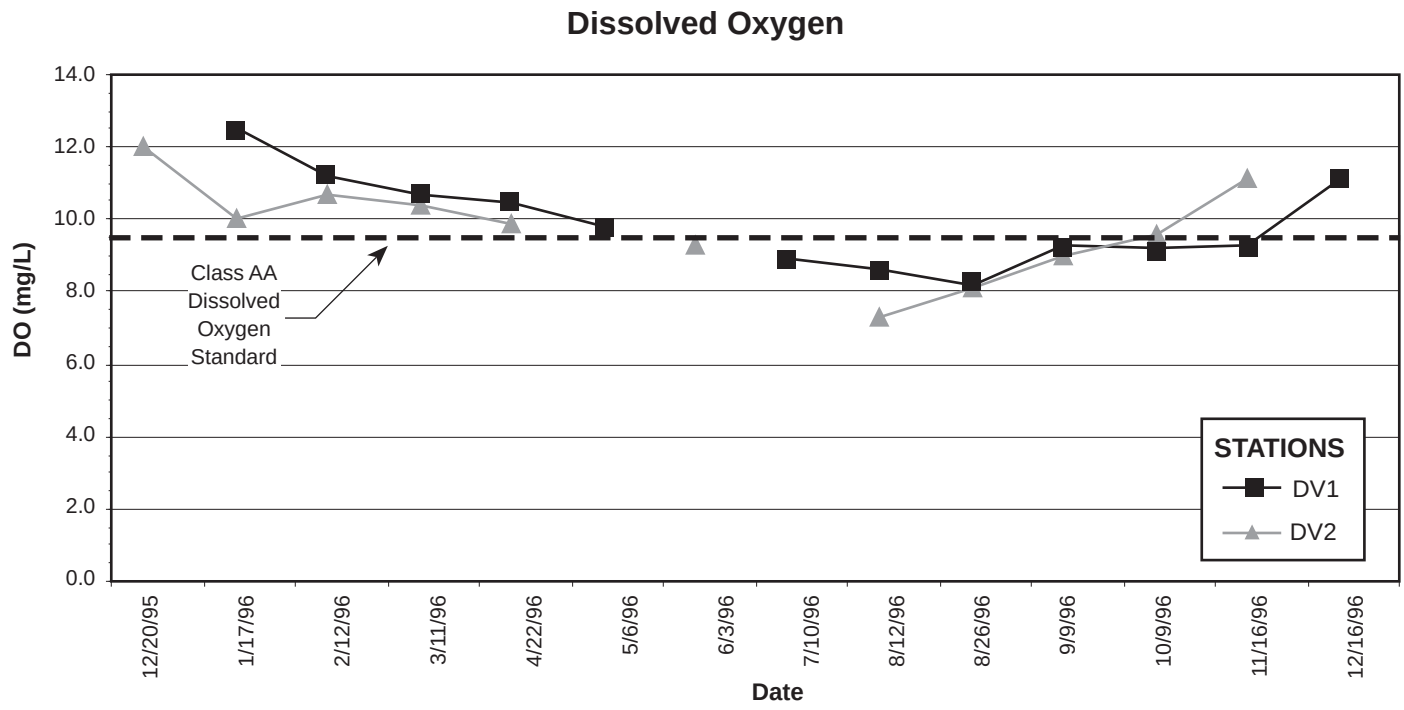
BOLD indicates exceeds state water quality standards.

Temperature data from the three Little Quilcene River stations are shown in Figure 9-2. Temperature at all three stations were similar, with the summer temperatures at LQ2 and LQ3 just exceeding the state water quality standard at 16.1 C on September 3, 1986. FC data was available from one station (LQ3) for the 1986 to 1989 period and is also shown on Figure 9-2. In general, FC levels at station LQ3, the station closest to the mouth, were higher then the upstream stations.

Water quality data (JCCD 2000) from stations DV1 (DV/0.1) and DV2 (DV/0.4) are shown in Figures 9-3 and 9-4 for data collected in 1995-1996. This data shows that as the temperature in Donovan Creek increased in the summer, the DO decreased, and vice versa in the winter. As shown in Figure 9-4, turbidity was highest during the spring. Fecal coliform concentrations tended to be highest during the summer and fall periods, with highest concentrations observed downstream.

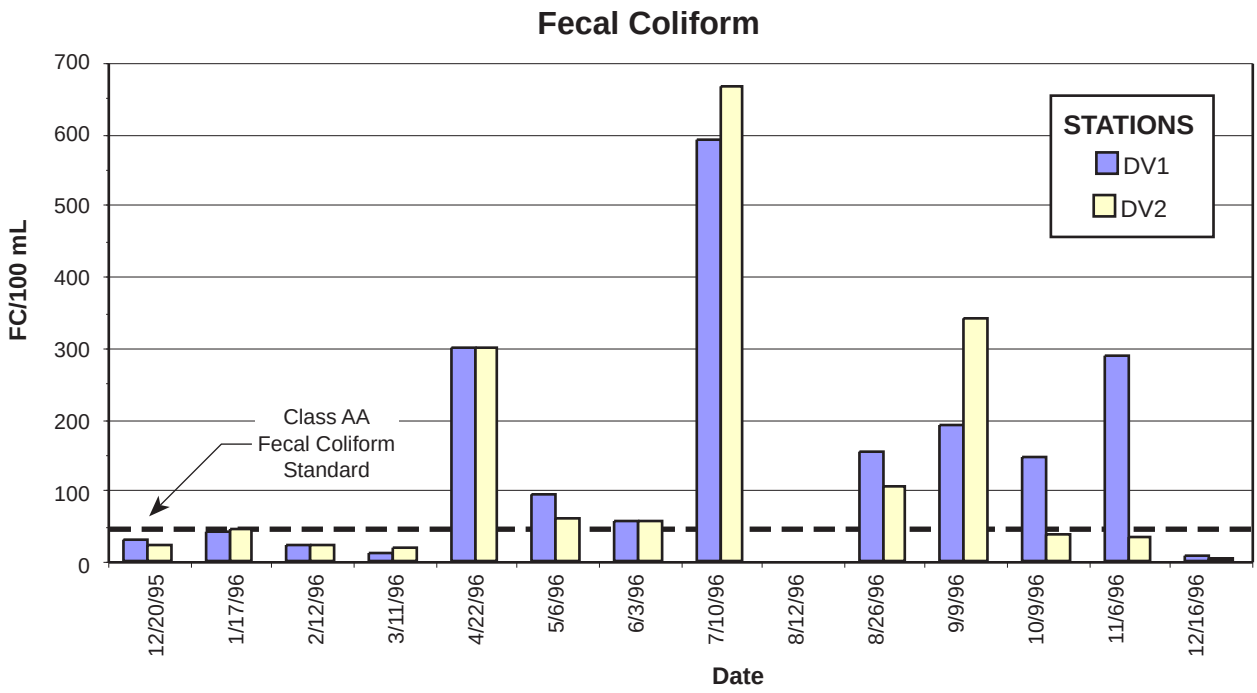
Jakeway Creek temperature and DO data from 1995 – 1996 are shown in Figure 9-5. Stations JK/0.1 and JK/0.2 are downstream of a pond, and these stations had the highest temperatures (25.4 and 24.9 C, respectively, much higher than the state water quality standard of 16 C. The highest temperatures and lowest DO levels exceeding state water quality standards occurred in summer at all four stations in

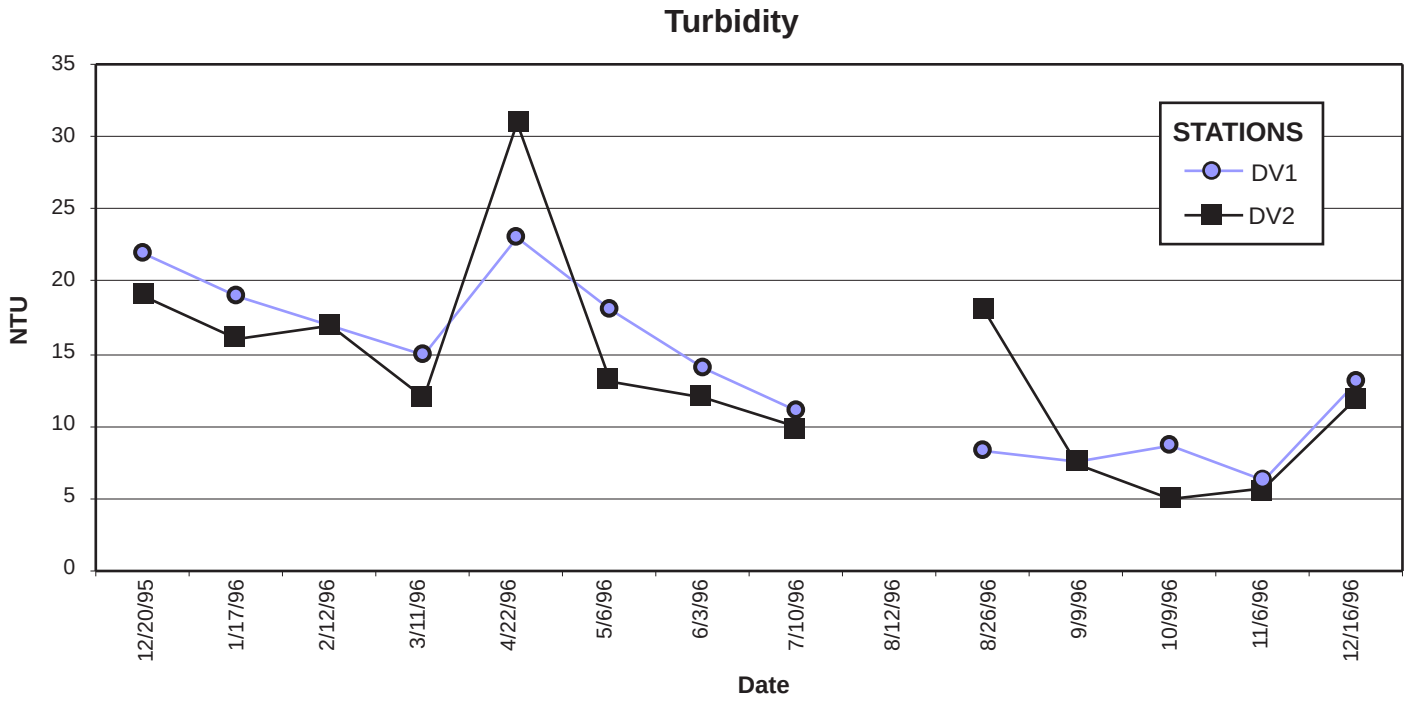




Source: JCCD

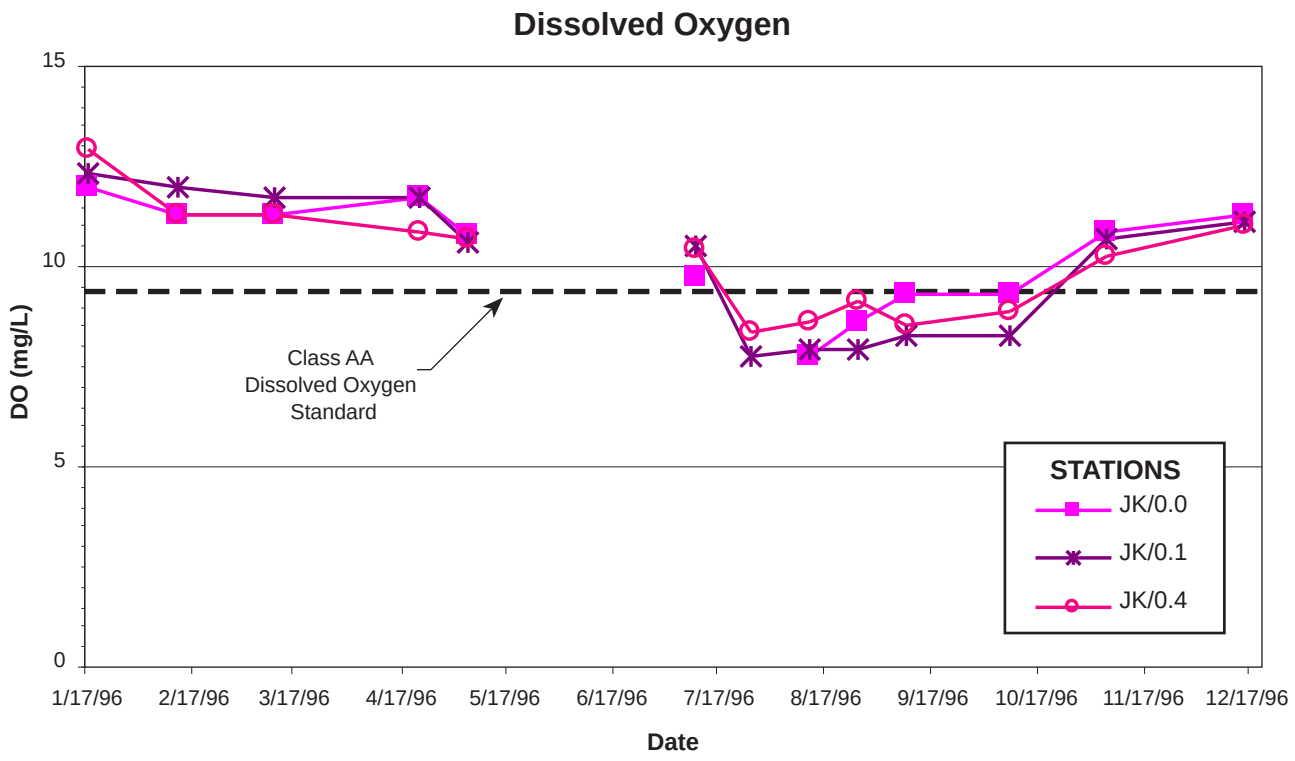
Figure 9-3
Temperature and Dissolved Oxygen in Donovan Creek, December 1995 – December 1996

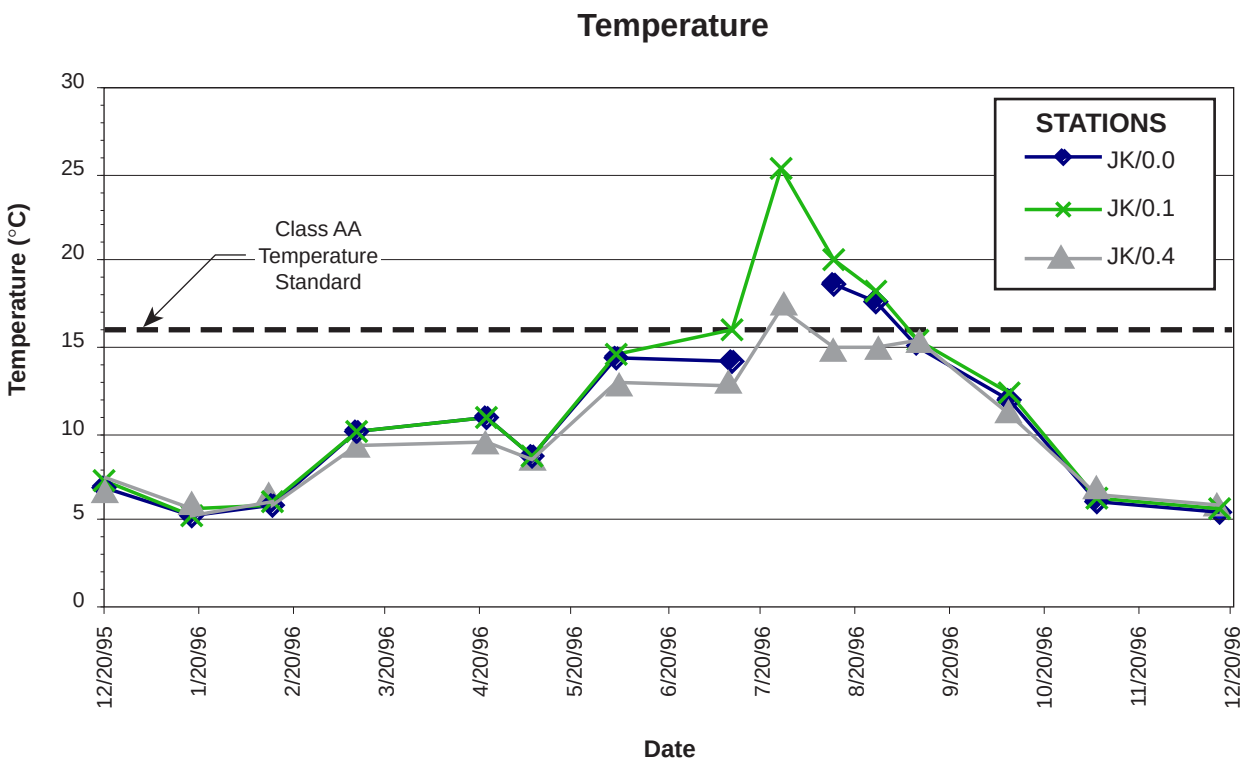




Source: JCCD

Figure 9-4
Fecal Coliform and Turbidity in Donovan Creek, December 1995 – December 1996





Source: JCCD

Figure 9-5
Dissolved Oxygen and Temperature in Jakeway Creek, December 1995 – December 1996

Jakeway Creek. Turbidity exceeded the state standard at station JK/0.2 July 10, 1996 (25 NTU change from JK/0.4).

Prior to 1997, the City of Port Townsend periodically tested water quality in the Little Quilcene River at the City diversion dam as part of their drinking water supply system monitoring program. Turbidity measurements have been taken continuously at the Little Quilcene River diversion since 1992.Water quality in the Little Quilcene River at the diversion has generally been excellent and similar to water quality observed at the Big Quilcene River at the City diversion dam. This testing program is summarized in Table 9-6.

Table 9-6. Little Quilcene River Water Quality Testing

Parameters	Testing Frequency	Meets Standards?	Comments
Volatile Organic Compounds	Annually	YES	Consists of 21 separate chemicals
Synthetic Organic Compounds	Annually	YES	Consists of 33 separate chemicals
Inorganic Chemicals	Annually	YES	Includes 15 metals and two nutrients
Inorganic Physical	Annually	YES	Includes turbidity and hardness

Source: City of Port Townsend (1998).

9.2.2 Marine Water Quality

All of the streams in this sub-basin drain to Quilcene Bay, which is discussed in the Big Quilcene Sub-basin section of this report.

9.2.3 Inventory of Potential Surface Water Contaminant Sources

9.2.3.1 *Point Sources*

The following NPDES permits and point sources have been identified in this sub-basin and are summarized below from Ecology (1999a):

- Lords Lake North
- Dam Lords Lake East Dam
- Trombley Hill Scalzo Dam
- Olympic Testing Lab USFS
- Quilcene Auto Shop Quilcene
- Lust Site Jefferson County PW Quilcene Pit

It is noted that NPDES point source locations have been provided by Ecology and in some cases may depict facility names and locations that may not be entirely representative of existing conditions. The Ecology database does also not distinguish between stormwater and/or wastewater permits. No specific monitoring data or compliance problems were available for these specific point sources.

9.2.3.2 *Non-point Sources*

In past years residential development and agriculture have been suspected as a source for the low levels of FC measured in the Little Quilcene River (Gately 1992). Livestock were fenced from the tidally inundated pasture in 1988. Livestock had access to the lower reaches of Donovan Creek, and have been identified as a significant source of FC in the stream especially during extreme high tide events (Welch

and Banks 1987; Gately 1992). Livestock fencing has been completed along portions of Donovan Creek, so it is difficult to determine whether livestock continue to create a FC load in this creek (Gately 1992). In general, Gately (1992) found that turbidity and total suspended solids were generally less at sites upstream of livestock grazing areas in Donovan Creek.

9.2.4 Summary of Surface Water Trends and Compliance Problems

Water quality compliance problems in this sub-basin consist of FC in Donovan Creek (JCCD 2000), and temperature exceedances in the Little Quilcene River (RM 2.0) (Bahls 1997), Donovan Creek (RM 0.1 – 0.4) (Bahls 1997a; JCCD 2000), Leland Creek (LL3) (JCCD 2000), and Jakeway Creek (RM 0 – RM 0.4) (JCCD 2000). Data also suggests that DO exceedances in Donovan Creek and Jakweway Creek could be a reoccurring problem in summer. Portions of Quilcene Bay also experience intermittent elevated FC concentrations.

Both DOH (1999b) and Gately (1993b) have observed a general trend of overall decreasing FC loading in this sub-basin; however, there is insufficient data to determine whether these trends are statistically significant, or whether the trends are due to climatic conditions more than an actual decrease from FC sources.

9.2.5 Groundwater Quality

Chloride concentrations in the Little Quilcene Sub-basin are mapped on Exhibit 4. All of the coastal wells, and the vast majority of inland wells, show chloride concentrations in the natural background range. Four inland wells show some degree of elevated chloride. Among these, chloride concentrations between 100 and 250 mg/l are noted along Donovan Creek and near Lake Leland, and concentrations between 50 and 100 mg/l are noted just north of the Big Quilcene River about 4,000 feet inland of Quilcene Bay. It appears that inland problems with elevated chloride may be more prevalent than coastal problems in both the Big and Little Quilcene Sub-basins under current levels of development.

Nitrate concentrations in the Little Quilcene Sub-basin are mapped on Exhibit 5. While only a moderate number of nitrate measurements are available from the Little Quilcene Sub-basin, many of these measurements show at least mildly elevated nitrate concentrations (1-2 mg/l) and several show concentrations exceeding 2 mg/l.

Sites on known groundwater contamination are limited to the vicinity of Quilcene, are described in Chapter 3.

9.3 WATER QUANTITY

9.3.1 Groundwater Quantity

Groundwater recharge estimated for the Little Quilcene sub-basin is approximately 14,650 af/yr, and averages 6.3 in/yr over the entire area. This moderate rate of recharge is largely controlled by the presence of bedrock, which covers approximately 62 percent of the sub-basin and till, which covers approximately 27 percent of the sub-basin. Exhibit 6 shows that recharge in non-bedrock areas varies from 10-15 in/yr over glacial till, to 25-35 in/yr in areas without till cover. Precipitation averages 47.5 in/yr over the sub-basin, and is likely to cause significant runoff from till- and bedrock covered areas. In places, a portion of this runoff is expected to infiltrate into local outwash/alluvial deposits and supplement recharge to both shallow and principal aquifers. As noted in Chapter 4, recharge is underestimated in a small portion of the Little Quilcene sub-basin along the western coast of the Bolton Peninsula. In this area, the Jefferson County soil survey (SCS 1975) inaccurately reported soils underlain by shallow

bedrock. However, the overall effect of this inaccuracy on recharge estimated for the entire sub-basin is likely insignificant.

9.3.2 Surface Water Quantity

The quantity of surface water in the Little Quilcene River sub-basin is affected by diversions by the City of Port Townsend. There is one active stream gage station operated by the City of Port Townsend at its diversion gage number 12051900. River stage is measured once daily by the City and converted to flows using a rating curve supplied by the USGS. A graph of the average streamflow and average diversion by the City is shown in Figure 9-6. The City has a water right to divert 9.56 cfs but is conditioned on a 6 cfs minimum instream flow. Their diversion has varied from 3.6 to 5.1 cfs on an annual basis.

Streamflow data from USGS gage operated in 1927 and 1951-56 was obtained and analyzed. Figure 9-7 shows the exceedance characteristics of the Little Quilcene River at the USGS gage. The USGS gage was located downstream from the City's diversion and has a drainage area of 23.7 square miles compared to 10.6 at the City's diversion dam.

Optimum instream flow for the Little Quilcene River and other streams in the sub-basin were summarized in the Draft Instream Flow Data Summary. The optimum instream habitat and flow for the Little Quilcene River are also plotted on Figures 9-6 and 9-7. The optimum chum salmon spawning flows are less than the 10 percent exceedance values for the Little Quilcene River during the months they are needed (September – October). The steelhead spawning flows range from about 50 percent exceedance to less than 10 percent exceedance during the months they are needed (February – May). The optimum coho salmon spawning flows have exceedance values ranging from less than 10 percent in October to 50 percent in December. The optimum flows for chinook salmon and steelhead rearing have exceedance values ranging from 90 percent in July to about 10 percent in September.

9.3.3 Estimate of Water Use and Allocation

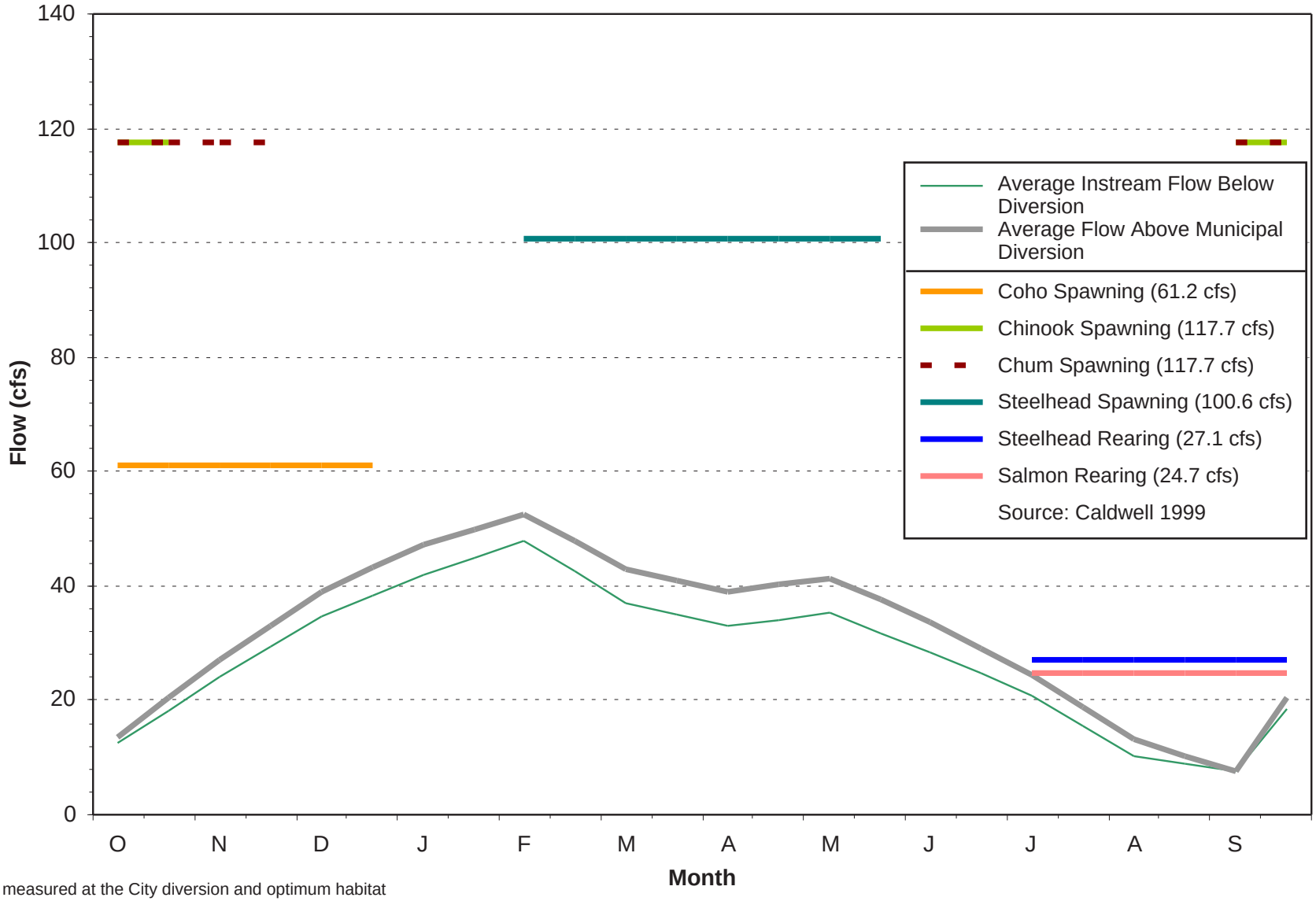
9.3.3.1 *Groundwater Use and Allocation*

Exhibit 11 shows the spatial distribution of groundwater use in the Little Quilcene sub-basin. The total groundwater withdrawal, assuming a domestic use of 250 gpd, is 287 af/yr. Approximately 38 percent of this total use is estimated from water rights and claims for irrigation purposes, and is qualified as being "lower accuracy" data. The remaining 62 percent (179 af/yr) is based on various sources for domestic and commercial uses, and is believed to be relatively high quality data. Given the general reliance on septic systems in the sub-basin, the consumptive portion of these domestic and commercial withdrawals is likely to be much lower than the total amount withdrawn.

In the Little Quilcene sub-basin, 10 groundwater rights have been issued for a total of 70 af/yr. The spatial distribution of groundwater rights is presented in Exhibit 8. Figure 9-8 presents a pie chart of groundwater rights by use and shows that approximately 70 percent of the total allocation is domestic uses, followed by 29 percent for irrigation.

Approximately 601 (exempt) single family wells are estimated for the Little Quilcene sub-basin, translating to a potential exempt allocation of 3,366 af/yr. However, only a small portion of this exempt allocation is likely to be actually put to use.

There are three water right applications in the Little Quilcene sub-basin, requesting a total Qi of 570 gpm. There are 144 groundwater claims in the sub-basin. Table 4-3 lists claims by use, and shows that 39 of



Note: Flow is measured at the City diversion and optimum habitat has been calculated at the mouth of the river.

Figure 9-6
Theoretical Optimum Habitat and Flow, Little Quilcene River
Average Flow at Municipal Diversion
Period of Record 1994-1999

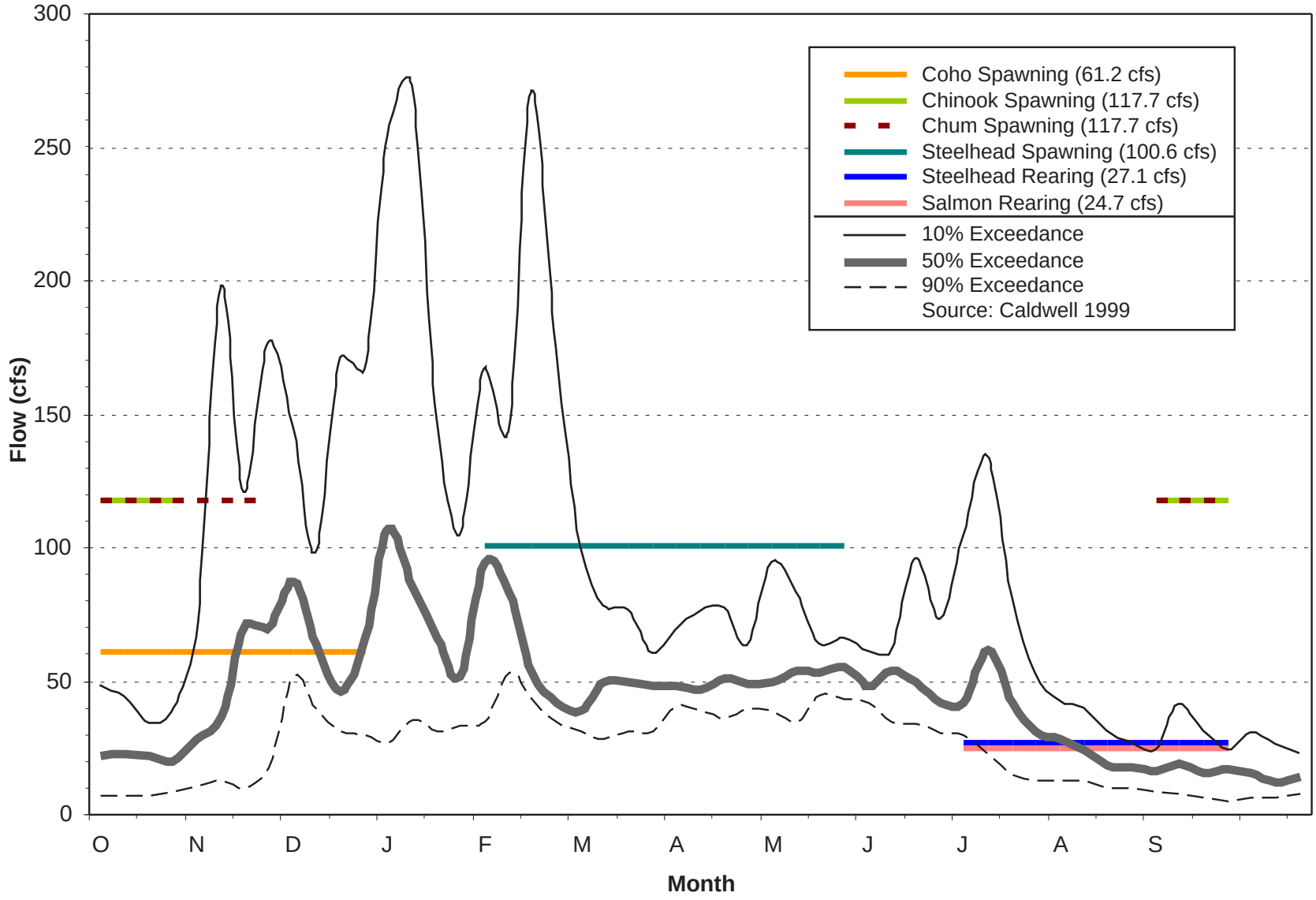
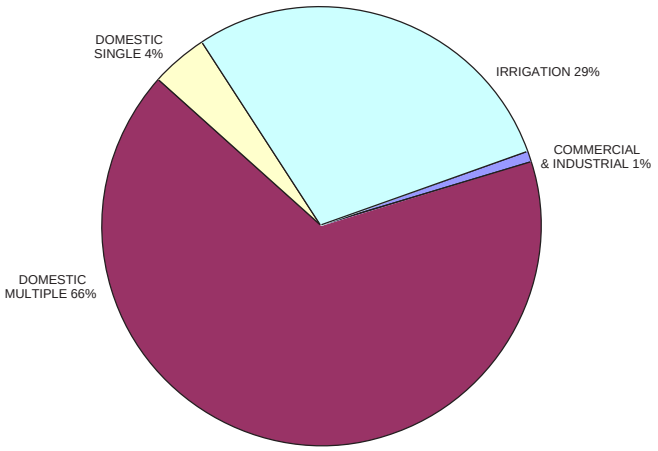


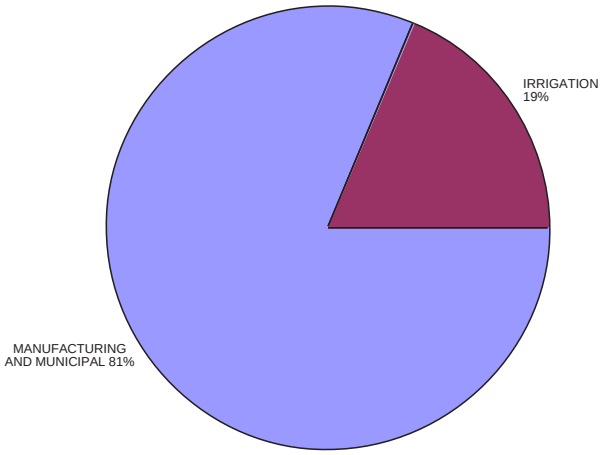
Figure 9-7
Theoretical Optimum Habitat and Flow, Little Quilcene River
USGS Gauge 12052200
Period of Record 1927, 1951-1956

GROUNDWATER RIGHTS (QA) BY USE



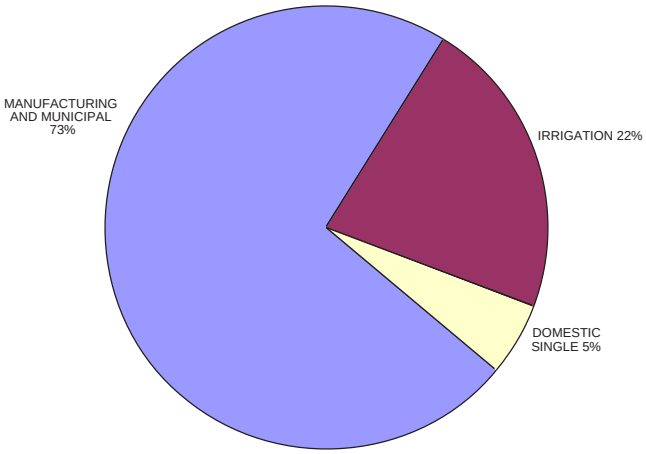
Note: total allocation = 70 af/yr, accounted by use = 70 af/yr, domestic domestic exempt wells = 3,366 af/yr

SURFACE WATER RIGHTS (QA) BY USE



Note: total allocation = 445 af/yr, accounted by purpose 540 af/yr, no additional non-consumptive rights as Qa

SURFACE WATER RIGHTS (QI) BY USE



Note: total allocation = 12.0 cfs, accounted by purpose = 13.2 cfs, additional non-consumptive rights = 0.6 cfs

Source: Ecology WRATs database

Figure 9-8
Little Quilcene Sub-Basin Groundwater and Surface Water Rights and Use, Consumptive Use Only

these claims list irrigation as a principal use. Typically, only a portion of claims listing irrigation as a purpose-of-use list numbers of irrigated acres. In the Little Quilcene sub-basin, water use associated with the reported numbers of irrigated acres amounts to 88 af/yr. If each claim is also assumed to include a domestic use, total claimed groundwater can be estimated at about 230 af/yr. The portion of these claims that have been actually put to use, and would qualify for a water right, is unknown.

9.3.3.2 *Surface Water Use and Allocation*

Table 9-7 shows the relative distribution of consumptive use water rights in the Little Quilcene sub-basin. The largest use of water is for municipal and manufacturing uses, comprising 73 percent of the total instantaneous quantity and 81 percent of the total annual quantity. The next largest use is for irrigation, followed by domestic single use. Figure 9-8 presents pie charts of the relative distribution of surface water rights. The total consumptive use rights are 11.95 cfs and 2,740 af/yr annual quantity. A quantity associated with the City's diversion was not listed in the database. The City's average diversion was used instead. Claims data indicate that 1.7 cfs are claimed with an annual quantity estimated at 170 af/yr. The claims data is not reflected on the pie charts. The spatial distribution of surface water rights (Qa), claims (Qi), and claims (Qa) are shown in Exhibits 12, 13, and 14, respectively.

Table 9-7. Analysis of Surface Water Allocation in Little Quilcene Sub-basin

Purpose	Percent Qi	Percent Qa
DM	0%	0%
DS	5%	0%
IR	22%	19%
MU/CI	73%	81%
ST	0%	0%

Explanation of Purpose Codes:

CI	Commercial and Industrial Manufacturing	FS	Fish Propagation
DM	Domestic Multiple	IR	Irrigation
DS	Domestic Single	MI	Mining
MU	Municipal	ST	Stock Watering
FR	Fire Protection		

9.3.4 Hydraulic Continuity Potential

Relative hydraulic continuity potential (RHCP), as shown on Exhibit 17, is ranked as "low" in the bedrock and till-covered areas that dominate the sub-basin and "medium" in the shallow alluvial and recessional outwash deposits present along streams above their mouths. Based on proximity and assumed similarity with the alluvial delta at the mouth of the Big Quilcene River, RCHP was ranked as "high" near the mouth of the Little Quilcene River. Uncertainty regarding similarity of hydrogeologic conditions at the mouths of Donovan and Jakeway Creeks led to a "medium-high" ranking for these areas.

9.4 HABITAT

9.4.1 Salmonid Stocks

9.4.1.1 *Summer and Fall Chum Salmon*

Summer and fall chum salmon comprise two genetically distinct stocks in the Little Quilcene systems. Summer and fall chum salmon are native to the drainage, but have been heavily influenced by hatchery production in the adjacent Big Quilcene River. The lower 1.8 miles are surveyed annual to index spawning escapement. Surveys of Leland Creek in December and January (Bahls 1994, 1995, 1996) counted from zero to 33 fall chum salmon spawning in the lower 1.3 miles of Leland Creek. The historical trend in fall chum salmon spawning escapement is shown in Figure 9-9. No fall chum salmon were observed in Donovan Creek during surveys in 1993 through 1995, but have been observed spawning up RM 3.0 in past years (Lichatowich 1996).

Summer chum salmon in the Big Quilcene and Little Quilcene rivers have not been genetically differentiated, so they are treated as a single stock. Early records of the QNFH shows that broodstock collections from the Little Quilcene River were less than 1,000 annually between 1912 and 1929 (Jablonski 2000). Summer chum salmon spawn in the Little Quilcene River up to RM 3.0, but primarily below RM 1.8 (Ames et al. 2000). Spawning escapement in the Little Quilcene also increased in the late 1970's (Ames et al. 2000), but declined thereafter, and was very low from 1989 to 1994 (Figure 9-10). Since 1995, escapement has increased, but is still low relative to levels in the 1970's. Summer chum salmon spawn below RM 1.8 in the Little Quilcene River.

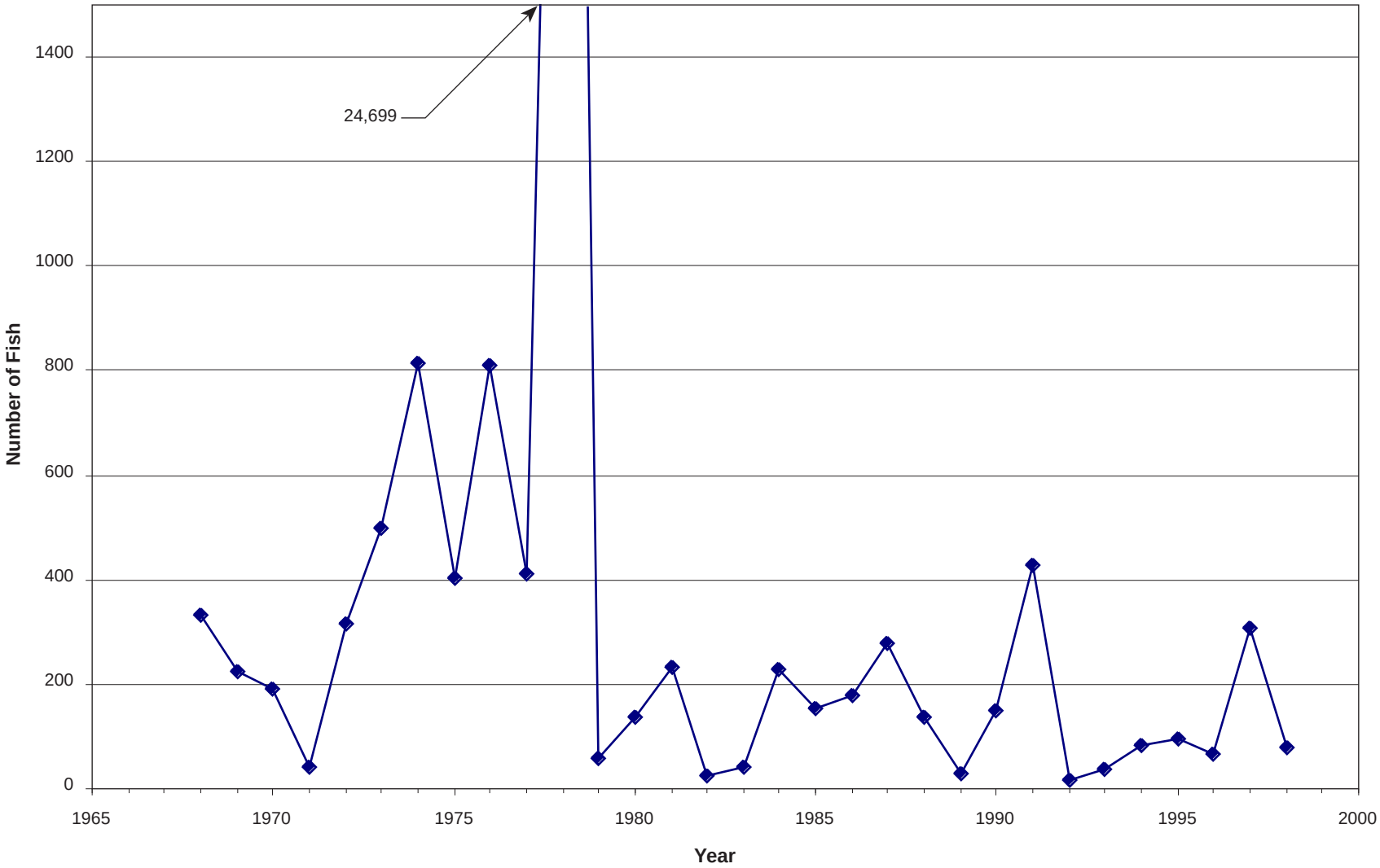
The aggregate Big Quilcene/Little Quilcene summer chum salmon stock is considered to be depressed, and habitat quality constrains production in both streams (Ames et al. 2000). The effective population size for the 1995 to 1998 returns was 41,087, so the current risk of extinction is low. In the period 1988 to 1991, however, the effective population was only 320, and extinction risk at that level is high.

9.4.1.2 *Coho Salmon*

Coho salmon that spawn naturally in the Little Quilcene basin and in adjacent streams such as Donovan Creek are thought to be of native origin. They return in September and October, with peak of spawning in early November. Coho salmon use the Little Quilcene up to RM 6.6, where a steep cascade presents a barrier to adult migration. Lichatowich (1993b) compared peak spawning times for Big Quilcene, Little Quilcene, and Dosewallips rivers and found little evidence for straying and interbreeding between Big and Little Quilcene systems. He concluded that the Little Quilcene stock retains life history traits suggestive of a native, early coho salmon stock.

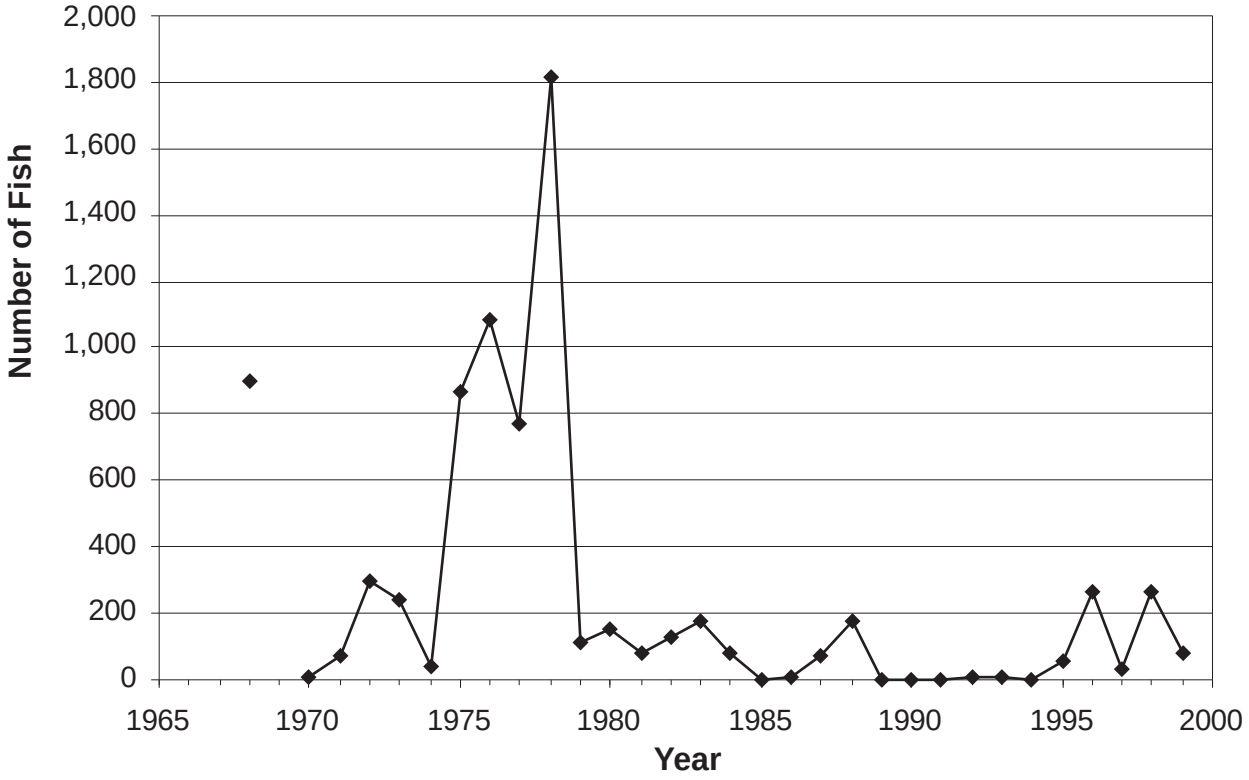
Naturally reproducing coho salmon in the Big and Little Quilcene rivers, and other streams draining into Quilcene and Dabob Bay, are accounted as a single unit by fishery managers. Coho salmon spawning escapement to streams entering Quilcene Bay and Dabob Bay is estimated in the aggregate from annual surveys of index reaches in Tarboo Creek (tributary 17.0130 RM 0.0 – 0.9) and the Little Quilcene River (RM 3.0 - 5.3).

Supplemental surveys have been conducted in recent years (see below) that provide additional data on spawning distribution and approximate numbers in several tributaries. Escapement has ranged from 200 up to 1,200 in the period between 1986 and 1998, and the terminal run size (i.e. that number of adults entering Hood Canal has ranged from 300 to 7,700 in that period (HCJTC 1999). Recovery of coded-wire tagged coho salmon at the QNFH rack, which were reared in the Quilcene Bay net pens, suggests



Source: WDFW, unpublished data.

Figure 9-9
Fall Chum Spawning Escapement to the Little Quilcene River



Source: Ames, et al., 2000.

Figure 9-10
Summer Chum Spawning Escapement to the Little Quilcene River, 1970-1999

that these pen-reared fish may comprise from 10 to 20 percent of the natural escapement in adjacent streams.

Supplemental escapement surveys confirm that a small and annually variable number of native coho salmon and some hatchery or pen-origin coho salmon spawn in the smaller tributaries of the Big and Little Quilcene rivers, as well as independent streams that drain into Quilcene Bay and Dabob Bay. Limited scale analysis confirms that some of these coho salmon were of hatchery or net pen origin (Bahls 1996). Surveys of Leland Creek conducted from 1992 to 1996 (Bahls 1994, 1995, 1996) found from zero to 24 coho salmon spawning in the lower 1.3 miles from early December through early January, which is suggestive of native origin. In Donovan Creek, up to 8 coho salmon were observed spawning between RM 1.2 and RM 1.9 in mid-December. Surveys in the mid-1970's observed much larger number of coho salmon, up to 145 fish/mile. Their later timing suggested they were of native origin, distinct from the early-timed hatchery stock in the Big Quilcene system.

9.4.1.3 *Chinook Salmon*

Adult chinook salmon that were observed spawning through the mid-1970's, and that are still occasionally observed, are probably strays from other Hood Canal natural or hatchery stocks. QNFH began broodstock collection from the Big Quilcene, Little Quilcene, and Duckabush rivers in 1911, but the egg supply was insufficient to meet program goals. No chinook salmon have been observed in the Little Quilcene since the mid-1970's.

9.4.1.4 *Steelhead*

Winter steelhead escapement is not regularly monitored in the Little Quilcene river or adjacent tributaries so their status is unknown (Lichatowich 1996; WDF et al. 1993). Very few steelhead were counted during supplemental surveys of several tributaries. One steelhead was seen in Leland Creek in January 1993 (Bahls 1994). Sport catch data from the 1970's show up to 200 winter steelhead harvested in the Big Quilcene River, and also a few summer steelhead. It is unlikely that summer steelhead are self sustaining, because these systems lack the required holding habitat (i.e. deep pools) during the base flow season.

9.4.1.5 *Other Species*

Anadromous and resident coastal cutthroat are present in the Little Quilcene system. The anadromous form is of special concern due to dramatic declines in abundance throughout the Puget Sound and Washington coast, but reliable estimates of abundance are not available in WRIA 17. Sturgeon have also been observed in the lower reaches of Donovan Creek.

9.4.2 Habitat Assessment

9.4.2.1 *Little Quilcene River*

Stream habitat has been surveyed in the mainstem Little Quilcene River (WRIA 17.0076) and its tributaries Howe Creek (17.0090), Ripley Creek (17.0089), and Leland Creek (17.0077). Information regarding Donovan Creek (17.0115), an independent stream entering Quilcene Bay just east of the Little Quilcene River, is also included in this section. Surveys using the TFW Ambient Monitoring protocol were completed for representative reaches in all these streams.

Channel Condition

The Little Quilcene River was surveyed in 1992 from the mouth to RM 5.2, the confluence with Howe Creek (Bernthal et al. 1999). In Segments 1 (RM 0.0 – 0.2) and 2 (RM 0.2 – 1.3) gradient is less than 1 percent and the channel is unconfined. Segment 1 is tidally influenced, and the channel is wide relative to the upstream segments due to the presence of beaver ponds. The channel is highly unstable, and confined by dikes in this segment, and contains very few pieces of LWD, none of which are key-sized. The substrate is predominantly sand and gravel.

In Segments 3 (RM 1.3 – 2.8), 4 (RM 2.8 – 3.2), and 5 (RM 3.2 – 3.3) the channel is moderately confined and the gradient between 1 and 2 percent. Segments 4 and 5 hold a higher amount of LWD, but pools are still infrequent. Channel substrate is predominantly gravel.

Spawning habitat is in poor condition in the Little Quilcene River. Low elevation areas were logged by 1930's and old growth cedars were cut early in the century. Starting in 1951 and for the next 20 years WDFW removed logjams in the lower river. LWD removal has "profoundly affected habitat and channel stability" (Bernthal et al. 1999) and scour studies are needed to determine if bed instability affects egg survival. Summer and winter rearing habitat is degraded, primarily because pools are infrequent and small. Pool parameter ratings are fair to poor

Riparian Zone

The riparian forest is young in Segment 2, but is more mature in Segments 3 and 5. The riparian zone below RM 3.0 is dominated by young deciduous or mixed-species forest, so LWD recruitment potential is low. LWD placement could improve habitat conditions below RM 3.0, but long term habitat recovery is likely dependent on re-establishing coniferous tree stands in the riparian zone.

Sub-estuarine Zone

Dikes along the lower river and parallel to the shore south of the river mouth have isolated the river channel from adjacent sloughs. Simenstad (in PNPTC et al. 1999) estimated that 25 percent of the historic delta area of 230 acres is diked along its western margin. A short stretch of causeway (0.45 miles) also may inhibit tidal inundation of the adjacent marshes.

Limiting Factors for Summer Chum Salmon

Summer chum salmon spawn up to RM 3.0, but primarily below RM 1.8. Access to tributaries, such as Leland Creek, is unlikely due to low flow. Chum salmon habitat is generally in poor condition, in particular below RM 0.8. Factors that have affected habitat quality include low flow, reduced channel complexity, estuarine diking, channel aggradation, and young or absent riparian cover.

Low flow during spawning has been identified as a potential high impact. However, the loss in spawning habitat has not been quantitatively linked to flow. Because there is little LWD present in the lower mainstem (0.1 pieces/m), pools are infrequent; they comprise only 32 percent of the channel area, and occur every 5.3 channel widths. Logjams noted in a 1932 survey are mostly gone. LWD removal has continued, and occurred as recently as 1995. Bank armoring has also reduced habitat diversity. Both of these factors have reduced the quality of chum salmon spawning and incubation habitat (Ames et al. 2000).

Channelization and diking of the lower river has caused aggradation and channel avulsions below RM 0.3, leaving the channel dry for several weeks during the base flow season (Johnson personal

communication cited in Ames et al. 2000). Sediment sources in the upper watershed have not been documented. Aggradation has been rated has having a moderate impact on chum salmon spawning and incubation success (Ames et al. 2000).

Flood control measures and causeway construction in the lower river, as described above, have isolated the river mouth from slough habitat. Restoring the connection between the lower river and its sub-estuary, by breaching the dikes and causeway, or other means, would restore access to 25 percent of the historic rearing and migration habitat (Simenstad 1999 cited in Ames et al. 2000).

9.4.2.2 *Howe Creek*

The Howe Creek drainage is 5.5 square miles, with the mainstem flowing southward 3.4 miles before joining the Little Quilcene River at RM 5.2. The upper portion of the drainage is confined, and moderately steep, with gradients less than 6 percent. Soils in this portion of the watershed consist of erosable glacial deposits of sand and gravel (Bernthal et al. 1999).

A full TFW Ambient Monitoring survey protocol was followed in characterizing habitat quality in five segments of Howe Creek between RM 0.0 and 2.8. Two intermediate segments (Segment 3 - RM 0.6 – 1.0, and Segment 4 – RM 1.6 – 1.7) are wetlands, which were not surveyed in detail.

Segment 1 (RM 0.0 – 0.4) flows through a steep confined, ravine with gradient between 6 – 17 percent. There is abundant LWD, with logjams forming pools and side channels, but 80 percent of the LWD is decayed. Pools are frequent but small in total area. The riparian zone is mature forest.

In Segment 2 (RM 0.4 – 0.6), the gradient is between 1 and 2 percent and the channel is unconfined. Segment 4 (RM 0.6 – 1.0) is unconfined with a gradient between 2 and 4 percent.

Segment 6 (RM 1.7 – 2.0) is unconfined with a gradient between 1 and 2 percent. Pools comprise 40 – 51 percent of the channel. There is more abundant LWD in Segment 2, and so pool frequency is higher. LWD is mostly decayed, so the streambed could become less stable. The channel substrate is primarily sand in Segment 2 and gravel in Segments 4 and 6.

Segment 7 (RM 2.0 – 2.8) is confined with a gradient between four and six percent. Pools are infrequent and shallow. LWD is scarce and decayed, and therefore unstable. The riparian zone is forested but the trees are young, small diameter. The channel substrate is 95 percent gravel.

The steep gradient in Segment 1 prevents passage by chum salmon, but coho salmon and steelhead are able to ascend the cascades at higher flow. The only suitable coho salmon spawning habitat is in Segment 6. Wetland areas in Segments 3 and 5 provide summer and winter rearing for coho salmon. There is potential for cutthroat in Segments 1 and 7. There are few deep pools throughout the stream, due to few key LWD pieces. Segment 6 and 7 typically go dry during summer. Temperature may be too high in Segments 2 and 4, where low canopy closure is a contributing factor.

9.4.2.3 *Ripley Creek*

Ripley Creek flows 3.5 miles to its confluence with the Little Quilcene River at RM 4.35. It has similar topography to Howe Creek a confined channel in the upper basin with gradient less than 6 percent. In the lower reaches gradient flattens to 2 percent or less. Both Howe and Ripley creeks provide rearing areas to coho salmon and cutthroat, except when the upper reaches dewater in summer. Ripley Creek was surveyed up to RM 1.5, but only the lower segment (RM 0.0 – 0.7) was assessed using the TFW protocol. There are no barriers to migration in the surveyed reaches.

In Segment 1 pools are large, but infrequent and shallow. The riparian zone is fully forested with mature deciduous and coniferous trees. Most LWD is suspended above the bankfull channel width, or is in the floodplain. LWD is 65 percent decayed, but most of it appears to be stable. The channel substrate is 47 percent gravel, 25 percent sand.

Spawning and incubation habitat is in fair condition, with some gravel between bedrock outcrops and cascades. LWD is more abundant than in the Little Quilcene River, but a lack of key pieces limits pool depth. LWD recruitment potential is good due to a fully forested riparian zone. Summer flow is extremely low, with some reaches completely dewatered (Bahls 2000 personal communication)

9.4.2.4 *Leland Creek*

Leland Creek is a tributary to the Little Quilcene River. It originates in Lake Leland, passes through a wetland, and under Leland Valley Road. The culvert under the road floods during high flow. The creek then flows south through open fields and thinly wooded land. Reed canary grass has invaded several reaches of the stream. Two miles below the lake it crosses Highway 101 through a box culvert. At high flow, water backs up here, stopping flow. Leland Creek joins the Little Quilcene River about one mile south of U.S. 101 highway crossing (PEI and Leland Watershed Community 2000).

The Leland Creek system was historically used by chum salmon, coho salmon and steelhead as far up as Lake Leland. The local residents believe that salmon and steelhead runs declined in the 1950's when local farmers dredged the upper reach to expand agricultural use (PEI and Leland Watershed Community 2000).

Anadromous fish access into Lake Leland was prevented in the 1950's by a weir, that was installed to prevent the egress of planted trout. This weir is no longer functional. Access into Leland Creek by summer chum salmon is unlikely due to low flow (Ames et al. 2000). Bahls (1996) observed up to 24 coho salmon spawning in the lower 1.3 miles of Leland Creek, and noted that substrate through most of this reach was composed of unsuitable, large, cobble. In 1992, this reach was dewatered and impassable in early November (Bahls 1993).

Culverts that block fish migration are currently limiting use of suitable spawning and rearing habitat by coho salmon and steelhead. Reed canary grass infestation in several reaches is reducing flow, and choking the stream channel. Lack of riparian tree cover is contributing to continued growth of reed canary grass. Domestic development in the valley may also be affecting water quality.

9.4.2.5 *Donovan Creek*

Donovan Creek is an independent drainage in the Little Quilcene Basin which flows into the northern end of Quilcene Bay, just east of the mouth of the Little Quilcene River. Tribal biologists evaluated three reaches in the Donovan Creek system: the mainstem from RM 0.0 to a barrier at RM 1.9, tributary 17.0116 from the confluence to RM 1.0, tributary 17.0118 up to RM 1.0 (i.e. up to Rice Lake). These surveys focused on the functionality of habitat with respect to the requirements of the different life stages of coho salmon, so the surveyed reaches cover the area accessed by adult and juveniles of this species. Overall habitat quantity has been reduced from historic levels. There has been moderate to substantial decline, mainly in the lower Donovan Creek mainstem, of spawning, fry colonization and overwintering habitat. Spawning and incubation habitat and summer rearing habitat has declined to a lesser extent. The principle causes of habitat loss have been associated with timber harvest and agricultural land use.

In the mainstem of Donovan Creek, sediment loading has affected spawning habitat most dramatically. Reduced channel stability, reduced in-stream habitat diversity, and high winter flow, have degraded

colonization and winter rearing habitat to a lesser extent. Former wetlands, which formerly provided high quality overwintering habitat, have been converted to agricultural use. Stream temperature exceeded state standards in late August 1992 (Lichatowich 1996).

The lower reach of tributary 17.0016 has been channelized and ditched, resulting in a small loss of spawning and incubation habitat. Functional habitat still exists in the upper end of the reach (PNPTC 1997 unpublished data).

Low and sometimes intermittent summer flow in tributary 17.0018 affects summer rearing habitat to a small degree. Productivity is greatly reduced in incubation, colonization, and overwintering habitat due to high winter flows, increased sediment load, decreased channel stability and loss of instream habitat diversity due to reduced LWD. The areas adjacent to Rice Lake were intensively logged from the 1970's to the mid-1980's. A culvert at Center Road near mouth of the tributary is a barrier at some flows. Rice Lake was formerly accessible to coho salmon, but a culvert near the outlet mouth may be a barrier (PNPTC 1997).

9.4.3 RESTORATION ACTIVITIES

Restoration projects that have been completed in this sub-basin are shown in Table 9-8.

Table 9-8. Summary of Completed Restoration Projects in the Little Quilcene Sub-basin

Stream	Date	Restoration Type	Description
Donovan Creek	12/30/1988	Riparian Fencing	20 acre conservation easement fenced
Donovan Creek	12/30/1988	Riparian Fencing	Shaw property
Donovan Creek	9/30/1994	Riparian Fencing	Butterfield property
Leland Creek	12/31/1992	Riparian Fencing	Jensen property
Leland Creek	12/31/1992	Riparian Fencing	Faith Farm
Jakeway Creek	2/6/1996	Riparian Fencing	Schmidt property
Jakeway Creek	10/30/1996	Salmon Habitat Restoration	Schmidt stream restoration project
Jakeway Creek	12/31/1999	Salmon Habitat Restoration	Stream improvements

Source: JCCD

No restoration projects are planned for the Little Quilcene sub-basin for 2000.

9.5 INSTREAM FLOW

Ecology and WDFW (1999) present toe-width study results for Leland Creek (RM 2.0), Howe Creek (RM 0.4), Donovan Creek (RM 1.0) and the Little Quilcene River (RM 1.0) (see Table 7-1). Species and lifestages considered included chinook salmon, coho salmon, chum salmon and steelhead spawning, and steelhead and salmonid juvenile rearing. Study results for Leland Creek range from a low of 12.5 cfs for salmonid juvenile rearing to a high of 65.7 cfs for chinook salmon and chum salmon spawning. Study results for Howe Creek range from a low of 6.1 cfs for salmonid juvenile rearing to a high of 35.2 cfs for chinook salmon and chum salmon spawning. Study results for Donovan Creek range from a low of 5.5 cfs for salmonid juvenile rearing to a high of 32.1 cfs for chinook salmon and chum salmon spawning. Study results for the Little Quilcene River range from a low of 24.7 cfs for salmonid juvenile rearing to a high of 117.7 cfs for chinook salmon and chum salmon spawning. These results can be used to develop instream flow recommendations for those streams. Results were not developed for Ripley Creek because no streamflow was present (see Table 6-1).

Hiss (1993) presents optimum instream flows for the Little Quilcene River, Leland Creek, Ripley Creek, Howe Creek, and Donovan Creek. An unnamed Donovan Creek tributary (17.0116) was evaluated but not measured because streamflow was determined to be seasonal. Species and lifestages considered were chum salmon, coho salmon and steelhead spawning, and coho salmon and steelhead rearing, as appropriate (see Table 6-3).

Orsborn and Orsborn (2000) are in the process of developing estimates of flood, average annual and low flow characteristics of the Little Quilcene River near its mouth.

9.6 FUTURE GROWTH AND POTENTIAL IMPACTS

9.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity

At the time of this writing, the only data available to characterize or predict future changes in land use were the population projections presented in Chapter 1. For several types of land use (e.g. logging and agriculture), the lack of specific information regarding anticipated future changes makes it impossible to predict related impacts to groundwater and surface-water quantities. General discussion of the relationships between these particular land uses, streamflow and groundwater recharge is included in Section 6.1.

The population projections and zoning patterns discussed above, however, can be used to qualitatively predict changes in patterns of residential and associated commercial land use. Increased population requires increased paved surfaces for homes, driveways, roads, and commercial infrastructure. In the Little Quilcene sub-basin, most of the projected growth is likely to occur in rural residential areas, and thus dense areas of paved surfaces are not expected. As indicated in Section 6.1, little direct data are available regarding the effects of paving on groundwater recharge at typical rural residential densities. While the effects of increased paving in rural residential areas are not expected to be substantial, some reduction in recharge may be associated with conversion of forested lands to meadows and lawns. Where growth occurs in the rural village center of Quilcene, increases in impervious area may cause locally increased runoff and reduced recharge unless appropriate stormwater management measures are taken. The effect of population increase on groundwater and surface water withdrawals is presented in a later section of this sub-basin assessment.

9.6.2 Population Growth

In 1996, the Little Quilcene sub-basin had approximately 1,308 residents (Jefferson County 2000). Little Quilcene sub-basin population growth over the next 20 years is estimated at 483 residents (Jefferson County 1998). Based on existing zoning (refer to Exhibit 1), the population growth will most likely occur in the town of Quilcene, along the lower two miles of the Little Quilcene River and along the Leland Creek corridor and Lake Leland shoreline.

9.6.3 Potential Impacts of Growth on Water Demand

Population in the Little Quilcene sub-basin is expected to increase by 37 percent between 1996 and 2016. Assuming that an average residence contains 2.2 people and uses 250 gpd, the projected increase of 483 people will cause an increased water demand of approximately 62 af/yr. Groundwater is currently the principal source of residential supply for most of the sub-basin, and is predominantly withdrawn by small public water systems and exempt wells. Additional demand will likely be satisfied by similar sources, although the residents of Quilcene have considered installation of a centralized public water system. If additional demand is met with the groundwater resource, estimated current groundwater withdrawals (287

af/yr for residential, commercial and agricultural purposes) would increase by about 21 percent. The increased demand also represents about 0.4 percent of estimated groundwater recharge (Table 3-2), with current groundwater withdrawals estimated at 2.0 percent. However, as discussed in Section 4.4, comparison of groundwater pumping with recharge cannot be reliably used as a direct indicator of groundwater availability.

Given the rural nature of the sub-basin, residential reliance on septic systems dictates that the consumptive portion of residential use is significantly less than the total residential groundwater withdrawal. Assuming that 87 percent of residential withdrawals are returned to the ground via septic infiltration (Solly et al. 1993), the actual increase in groundwater consumption would be on the order of 8 af/yr.

9.6.4 Potential Impacts of Growth on Habitat

Further growth has potential to effect water quality riparian habitat and streams channel morphology. Currently there are no significant water quality problems limiting fish productivity in the Little Quilcene sub-basin, with the exception of elevated fecal coliform levels in certain reaches that are attributed to the presence of livestock adjacent to streams. Elevated bacterial levels may be an indicator of undocumented nutrient loading, which can have consequences for benthic invertebrate production. Further data is required to demonstrate whether summer water temperature exceeds the tolerance limits of resident and early-spawning salmonids. Deforestation of the riparian zone may exacerbate the elevation in water temperature, particularly when stream flow is low.

Stream and riparian habitat restoration and protection in the Little Quilcene and adjacent independent basins will focus on the requirements of summer and fall chum salmon and coho salmon. Opportunity exists currently to protect sections of stream corridors which retain functional riparian buffers and provide relatively high quality spawning and rearing habitat. Examples of these areas include certain reaches of Howe Creek and Ripley Creek. However, most of the riparian zone along the Little Quilcene River and Donovan Creek and its tributaries is highly degraded and will not begin contributing vital LWD to these streams until the forest recovers. Since all of the riparian zone is in private ownership, initiatives to replant conifers and discourage further removal of LWD from streams may help to off set potential future impacts.

In the Leland Creek basin citizen support for habitat restoration is already well organized. A restoration plan written by the citizens' group (PEI and Leland Watershed Community 2000) contains specific goals and objectives for removing barriers to migration, restoring a functional riparian zone, and re-establishing native vegetation.

9.6.5 Conservation Options

Potential Conservation options that may be applicable for water users that divert from the Little Quilcene River or use groundwater in the Little Quilcene Sub-basin are summarized below.

- Tiered Water Rate Structures
- Modification of Landscape Irrigation Practices
- Water Conservation in Water Supply Systems and Individual Homes
- Educational programs
- Increased Storage, Either Through Surface Storage Or Aquifer Storage
- Water Conservancy Boards To Facilitate Water Rights Transfers
- Implement water conservation at Port Townsend Paper Company

9.7 DATA SYNTHESIS AND INTEGRATION

Population growth has been projected to increase 38 percent by 2016 in the Little Quilcene area, and will concentrate along the lower Little Quilcene River and Leland Creek. Hydraulic continuity potential was rated high in the lower Little Quilcene River basin, and medium-high in the lower Donovan Creek and Jakeway Creek basins. This Stage 1 analysis has not developed detailed enough information about land use to estimate the extent to which increased population increase the density of residential development in these zones of high and medium-high continuity potential. The effect of existing groundwater withdrawal on streamflow is also not understood, but ongoing studies are expected to assist in defining this relationship (Ames et al. 2000). Akin to the current water use distribution in the Big Quilcene River sub-basin, current domestic surface water rights comprise only 5 percent of the total surface water allocations in the sub-basin. Ecology has closed the basin to further surface withdrawals, but the effect of domestic groundwater withdrawals could be significant.

Currently there are no significant water quality problems in the Little Quilcene sub-basin, with the exception of elevated fecal coliform levels in certain reaches that are attributed to the presence of livestock adjacent to streams. Elevated bacterial levels may be an indicator of undocumented nutrient loading, which can have consequences for benthic invertebrate production. Further data is required to demonstrate whether summer water temperature exceeds the tolerance limits of resident and early-spawning salmonids. Extensive deforestation of the riparian zone may exacerbate the elevation in water temperature.

Stream and riparian habitat restoration and protection in the Little Quilcene and adjacent independent basins will focus on the requirements of summer and fall chum salmon and coho salmon. Opportunity exists currently to protect sections of stream corridors which retain functional riparian buffers and provide relatively high quality spawning and rearing habitat. Examples of these areas include certain reaches of Howe Creek and Ripley Creek. However, most of the riparian zone along the Little Quilcene River and Donovan Creek and its tributaries is highly degraded and will not begin contributing vital LWD to these streams until the forest recovers.

9.8 DATA QUALITY, DATA GAPS AND LIMITATIONS

In addition to the general data gaps identified for the entire WRIA, the following specific data gaps have been identified for this sub-basin:

9.8.1 Water Quality

Data gaps for the Little Quilcene sub-basin are the same as those for the Big Quilcene sub-basin.

9.8.2 Water Quantity

Water quantity data gaps have been identified for the entire WRIA and generally apply to the Little Quilcene sub-basin. The following additional definition of data gaps is based on consideration of currently existing data, and provides additional detail where possible:

- Hydrogeologic characterization is largely lacking in the lowlands of the Little Quilcene sub-basin. Conditions in the deltaic aquifer and the till covered areas immediately upstream could be better characterized through hydrogeologic cross-sections and water-level maps.

- Hydraulic continuity between the Little Quilcene River and the deltaic aquifer at the river mouth, as well as other upgradient aquifers have not been well defined. Better understanding of

hydraulic continuity will allow improved predictions of the impacts of additional groundwater development on stream baseflows.

- Recharge to bedrock areas could be better defined based on baseflows from bedrock dominated portions of the sub-basin and consideration of snowmelt throughout the year.

- Quantities of groundwater flow from bedrock to adjacent unconsolidated sediments are unknown. Such estimation can only be achieved with extensive hydrogeologic characterization, including definition of aquifer occurrence, aquifer properties, and groundwater level gradients.

- Revised definition of soil characteristics on the western coast of the Bolton Peninsula, specifically regarding the absence of shallow bedrock, is required to update recharge estimates for this area.

- Studies are needed to quantify the extent to which groundwater withdrawals in the adjacent Big Quilcene basin may affect flow in the Little Quilcene.

9.8.3 Habitat

- An assessment of the relationship between flow and spawning habitat for summer chum salmon in the lower mile of the Little Quilcene River, to determine the flow that may be required to meet natural chum salmon production goals.

- Inventory sediment sources in the drainage to assist in preparing a plan to reduce streambed aggradation in the lower basin.

- An assessment of potential methods of restoring tidal slough channels in the sub-estuary by re-structuring existing causeways.

- Quantify streambed scour in the lower 0.9 miles of the Little Quilcene River, and its effect on chum salmon egg survival.

- Catalogue the small unnamed streams that have potential to support cutthroat trout and possibly other salmonids.

9.8.4 In-stream Flow

Instream flow data gaps for this sub-basin are the same as that identified for the entire WRIA. There is sufficient information to develop instream flow recommendations and to proceed with the setting of instream flows in most of the larger streams in the basin.

10. DABOB – THORNDYKE SUB-BASIN

10.1 SUB-BASIN DESCRIPTION

The Dabob-Thorndyke sub-basin is located on the Bolton and Toandos Peninsulas (Figure 10-1). This sub-basin has a total of 39 identified streams; however, Tarboo and Thorndyke Creek are the only significant drainages (Williams et al. 1975). The majority of water features in this sub-basin are less than a mile long (Lichatowich 1993a).

10.1.1 Surface Water Features

Tarboo and Thorndyke creeks along with a series of smaller streams on the Toandos Peninsula are present in this sub-basin. Headwaters for Tarboo Creek begin 5 miles north of the inlet to Tarboo Bay at an elevation of 600 ft, and drain south to the head of Dabob Bay. A branch of the creek near the headwaters begins about one-quarter mile from Tarboo Lake. There is no mapped inlet or outlet to this lake. Combining all mapped tributaries with the main creek results in a total length for Tarboo Creek of 14 miles. It drains a basin of 12.4 square miles. Miscellaneous streamflow measurements taken on Tarboo Creek by the USGS were reported in the Dungeness-Quilcene (DQ) Plan (Jamestown S'Klallam Tribe 1994). Those measurements were 4.43 and 2.54 cfs in July and August of 1993, respectively. The upper reaches have intact, second-growth forest in the riparian zone. Some beaver ponds are present. The lower 0.5 mile is a high-quality, forested reach which was protected as critical habitat by WDFW in 1999. The Department of Natural Resources Natural Heritage Program also protects estuarine wetlands and forested slopes on the east and west sides of the bay.

The main stem of Thorndyke Creek begins in the northern region of the sub-basin at Sandy Shore Lake, and drains south to Thorndyke Bay on the east side of the Toandos Peninsula. The drainage area (12.1 square miles) for Thorndyke Creek has a number of wetlands and seasonal lakes in the highland areas. Combining flow from Sandy Shore Lake with additional inflow from tributaries results in a stream of 13 plus miles in length. Miscellaneous streamflow measurements taken on Thorndyke Creek by the USGS were reported in the DQ Plan (Jamestown S'Klallam Tribe 1994). Those measurements were 6.95 and 4.90 cfs, as measured at USGS staff-gages in July and August of 1993, respectively. Surface water features are summarized in Table 10-1.

Table 10-1 Fresh Water Features in the Dabob-Thorndyke Sub-basin.

Main Water Feature	Tributary	Length (miles)	Ecology Class
Tarboo Creek		6.8	Class AA
	Coyle Creek (RM 0.5)		Class AA
Thorndyke Creek		6.3	Class AA
	Sandy Shore Lake		Class AA

Source: Williams et al. (1975).

10.1.2 Groundwater Features

Hydrogeologic characterization in the Dabob-Thorndyke sub-basin is limited to existing maps of surficial geology, several geologic cross-sections crossing the sub-basin (PGG and EES 1994; Grimstad and Carson 1981), and limited discussion of potential well yields (ibid). Exhibit 13 shows the generalized surficial geology for the area. The groundwater flow system for the sub-basin is characterized by extensive areas covered by glacial till, bands of principal aquifer exposures along the coastlines of the Bolton and Toandas peninsulas, and north-south trending channel deposits incised into principal aquifer

Bywater Bay
Paradise Bay
ats Bay
Port Ludlow
Ludlow Bay
Teal Lake
Squamish Harbor
Shine Creek
Ludlow Creek
Thorndyke Bay
Thorndyke Creek
Horseshoe Lake
Sandy Shore Lake
Lake Ludlow
Silent Lake
Toandos Peninsula
Tarboo Bay
Tarboo Creek
Boulton Peninsula
Dabob Bay
Tarboo Lake
Donovan Creek
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Leland Creek
Ripley Creek
Howe Creek
Lords Lake
Andrews Creek
Trapper Creek
Perrin Creek
Spencer Creek
Maple Creek
Jackson
Dry Creek
Townsend Creek
Tunnel Creek
FIGURE 10-1 DABOB-THORNDYKE SUBBASIN
WRIA 17 Boundary
Sub-basin Boundary
River Mile
Streams
Water Bodies
1" = 12,500'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.

materials in inland locations. Bedrock is present on portions of the southern and eastern coastlines of the Bolton Peninsula, and along the western side of Tarboo Creek. Bedrock likely limits the thickness of unconsolidated sediments on the Bolton Peninsula but is likely much deeper on the Toandos Peninsula (Grimstad and Carson 1981). The bedrock is sedimentary in origin and typically yields little water (Grimstad and Carson 1981). Principal aquifer materials are comprised of Vashon advance outwash and stratified pre-Vashon sediments. Potential well yields from these sediments are typically low to medium (PGG and EES 1994).

10.1.3 Land Use

The land use in the Thorndyke Creek and Tarboo Creek sub-basin has not been analyzed in detail (Jefferson County 2000). The majority of the land use is within commercial forestry, rural forestry, and inholding forestry land use zones (71 percent of total). There are no forest lands under federal ownership in these two watersheds. Residential lands comprise approximately 23 percent of the sub-basin with the primary residential land use of one dwelling unit per five acres. Agricultural use, primarily in the low land valley, has been estimated at 7.3 percent (Welch and Banks 1987; Gately 1992). Existing land use in this sub-basin is shown in Table 10-2.

Table 10-2. Dabob-Thorndyke Sub-basin Land Use.

Description	No. of Parcels	Acres	% of Total Area
Rural Residential (1:5)	1,443	3,971	11.7%
Rural Residential (1:10)	91	517	1.5%
Rural Residential (1:20)	290	3,363	9.9%
Parks, Preserves, Recreation	3	33	0.1%
Rural Forest	74	2,036	6.0%
Commercial Forest	248	22,034	64.9%
Inholding Forest	20	184	0.5%
Military Reservation	16	758	2.2%
Commercial Agriculture	12	292	0.9%
Water and Tidelands	198	364	1.1%
Roads and Right of Ways	102	379	1.1%
Totals	**2,497**	**33,931**	**100.0%**

Source: Jefferson County (2000).

10.2 WATER QUALITY

10.2.1 Surface Water Quality

Freshwater quality data sources for this sub-basin are summarized in Table 10-3. In general, temperature and FC exceed state water quality standards in Tarboo Creek at TB2 and TB3 (Gately 1992; JCCD 2000). Temperature and FC levels in Coyle Creek generally are below state water quality standards (JCCD 2000).

Water quality data collected in 2000 by the JCCD in Tarboo Creek was limited to two sampling dates in January and February at RM 0.9 and RM 4.0. Although temperature, pH, FC, conductivity, and DO were in compliance with water quality criteria, not enough data was collected to determine trends over the course of four seasons, or compliance with state standards during the summer months at these two

locations. TSS and turbidity levels were significantly higher at RM 0.9 as compared to RM 4.0, exceeding the state water quality standard for turbidity with an increase of 10 NTU and 29 NTU in both January and February 2000, respectively.

Table 10-3 Water Quality Data Available for Dabob-Thorndyke Sub-basin

	Parameters					
Survey Areas	**Temperature**	**Turbidity**	**Cond.**	**Years Sampled**	**No. of Sample Locations**	**Reference**
Tarboo	X			1992	1	Bahls (1993)
East Fork Tarboo	X			1992	1	Bahls (1993)
Thorndyke	X			1992	1	Bahls (1993)
Tarboo Creek	**p**		**p**	1991	3	Gately (1992)
Coyle Creek	**p**			1986 - 1987	1	JCCD (2000)
Tarboo Creek	**p**	X	**p**	2000	2	JCCD (2000)

X = water quality was exceeded for at least one sample

p = no water quality criteria was exceeded (passed)

FC was sampled at three locations on Tarboo Creek and one location on Coyle Creek from 1986 to 1989 (Table 10-4). All sampling stations had GMVs that exceeded at least one element of the state FC standard (Rubida and Calambokidis 1990). The general trend was for increasing FC concentrations at the lower stream stations, and the investigators noted that FC concentrations seemed to improve during the study period. FC standards were exceeded at TB2 and TB3 (Gately 1992; JCCD 2000). FC levels were elevated in Tarboo Creek (TB2) in summer 1986, but data was not collected at that sight the next summers to determine if elevated FC levels are a regular occurrence. Elevated FC levels were found in Coyle Creek (CY1) in both summers of 1986 and 1987, showing a decrease by 1988.

Table 10-4 Tarboo Creek Fecal Coliform Monitoring Data

	Monitoring Year FC GMV (FC/100mL)		
Station	**1986-1989[a]**	**1991[b]**	**1986 – 1988[c]**
TB 1	33	5	32
TB 2	36	**108**	**133**
TB 3	36	**88**	**97**
CY 1	34	4	14

Bold = exceeds standard.

Source:

a: Rubida and Calambokidis (1990)

b: Gately (1992)

c: JCCD (2000)

During 1992, Bahls monitored temperature in Tarboo and Thorndyke Creeks every 7 to 10 days between August 4 and October 2. High temperatures were recorded; however, because the riparian cover at each site was relatively dense canopy, the reason for the high temperatures was unknown (Lichatowich 1993a).

Gately (1992) monitored temperature, TSS and conductivity on Tarboo and Coyle Creek during February and March 1991. Results from this study indicate that conductivity and total suspended solids were generally less at sites upstream of livestock grazing areas (Gately 1992).

10.2.2 Marine Water Quality

This sub-basin has three distinct marine water features: Thorndyke Bay, Tarboo Bay, and Dabob Bay. Water Quality in Thorndyke Bay is generally considered good. The DOH performed a comprehensive sanitary investigation between 1993 and 1998 and approved this area for shellfish harvesting (DOH 1999a). The results from DOH monitoring within this sub-basin are summarized in Table 10-5.

Table 10-5 Fecal Coliform Monitoring in Thorndyke and Dabob Bays for 1993-1998

Station	Bay	No. of Samples	Range	Geometric Mean	Meets Standard
11	Thorndyke	30	1.7-31.0	2.1	Yes
12	Thorndyke	30	1.7-13.0	2.0	Yes
13	Thorndyke	30	1.7-7.8	1.9	Yes
14	Thorndyke	30	1.7-7.8	1.9	Yes
15	Thorndyke	30	1.7-4.5	1.8	Yes
8	Dabob	30	1.7-7.8	1.8	Yes
9	Dabob	30	1.7-4.5	1.7	Yes
10	Dabob	30	1.7-6.1	1.9	Yes
11	Dabob	31	1.7-27.0	2.2	Yes
12	Dabob	31	1.7-11.0	1.8	Yes
13	Dabob	31	1.7-2.0	1.7	Yes
14	Dabob	31	1.7-11.0	1.8	Yes
15	Dabob	31	1.7-2.0	1.7	Yes
17	Dabob	31	1.7-13.0	2.0	Yes
22	Dabob	27	1.7-23.0	2.0	NA
23	Dabob	27	1.7-4.5	1.7	NA
24	Dabob	28	1.7-7.8	1.9	NA
25	Dabob	25	1.7-11.0	2.1	NA

Source: DOH (1999a)

Additional studies have been conducted to identify and quantify FC sources in Dabob Bay. Cleland (1984) monitored FC at 15 locations in June 1984 in Dabob Bay. Median concentrations at all sites were less than 1.9/100 mL, and the study concluded that the Bay met shellfish harvesting standards (Cleland 1984). Rubida and Calambokidis also monitored water quality in Dabob Bay at four locations during 1986-1989 (Table 10-6). All sampling sites met shellfish harvesting standards and were generally lower than FC concentrations found in Quilcene Bay. It was noted that FC concentrations at the upper end of Dabob Bay were significantly associated with FC loading in Coyle and Tarboo creeks (Rubida and Calambokidis 1990).

10.2.3 Inventory of Potential Surface Water Contaminant Sources

Point and non-point pollutants sources have been identified based on the studies discussed above and data from Ecology, the Forest Service, and County databases.

Only two NPDES point sources of pollutants have been identified in this sub-basin: Big Lake Outlet Structure and Jefferson County PW Coyle Pit (Ecology 1999a). It is noted that NPDES point source locations have been provided by Ecology and in some cases may depict facility names and locations that may not be entirely representative of existing conditions. The Ecology database does also not distinguish between stormwater and/or wastewater permits. No specific monitoring data or compliance problems were available for these specific point sources.

Table 10-6. Fecal Coliform Monitoring Results in Dabob Bay for 1986-1989

Station	Geometric Mean	Meets Standard
D1	2.8	Yes
D2	1.8	Yes
D3	1.8	Yes
D4	2.0	Yes

Source: Rubida and Calambokidis (1990).

Studies in this sub-basin have concluded that the main water quality threat is FC contamination due to three potential sources: agricultural practices, failing OSS, and native populations of harbor seals (Welch and Banks 1987; Rubida and Calambokidis 1990). Agricultural practices in the Tarboo Bay basin were identified as the primary source of FC in this area (Welch and Banks 1987; Quilcene/Dabob Bay Watershed Management Committee 1991).

10.2.4 Summary of Surface Water Trends and Compliance Problems

Tarboo and Thorndyke creeks have both been listed on the Ecology 303(d) list for exceeding temperature criteria for Class AA streams. Data submitted by Bahls (1995-1997) indicated that temperatures in Tarboo Creek exceeded the criteria at RM 2.5, and on the East Fork of Tarboo Creek at RM 0.5, in both 1992 and 1994. Data submitted by Bahls (1995-1997) also indicated that temperatures in Thorndyke exceeded the criteria at RM 1.1 between 1992 and 1994.

Tarboo Creek has also exceeded FC criteria at three locations on the main stem and one location on Coyle Creek.

Dabob and Thorndyke Bay meet state FC standards for Class AA water bodies. Ecology has not placed either of these water bodies on the 303(d) list, and descriptions of these water bodies indicate that ambient water quality is generally considered to be good.

10.2.5 Groundwater Quality

Chloride concentrations in the Dabob-Thorndyke Sub-basin are mapped on Exhibit 4. Water quality data are available mostly from wells scattered along the coast, and population densities are too low to identify (or to cause) clustered areas of elevated chloride. Isolated coastal occurrences of chloride concentrations exceeding 100 mg/l occur west of Coyle and on the western shore of Dabob Bay, and an inland occurrence is noted along Coyle Creek. Forbes and CH2M Hill (1993) notes that the chloride concentration in a well at Coyle showed an increase in chloride concentration from 56 mg/l in 1978 to 87 mg/l in 1993. Two isolated instances of mildly elevated chloride concentrations (50 to 100 mg/l) are noted near Coyle and Thorndyke Bay. In general, however, chloride concentrations in the natural background range (<50 mg/l) far outweigh elevated concentrations. Due to the relatively low population density in the sub-basin, it cannot be determined whether these low concentrations suggest reduced susceptibility to saltwater intrusion or simply less stress on the groundwater flow system.

Elevated nitrate concentrations are scattered throughout the Dabob-Thorndyke sub-basin, as shown on Exhibit 5. Two wells with highly elevated nitrate (5 to 10 mg/l) are noted along Tarboo Creek, several wells with elevated nitrate (2 to 5 mg/l) occur in coastal locations, and a relatively high percentage of wells show concentrations exceeding 1 mg/l. No clustering of high nitrate is observed. Despite the apparently higher incidence of (at least) mildly elevated nitrate concentrations, most wells show concentrations far below the State drinking water MCL.

No incidents of anthropogenic groundwater contamination have been diagnosed in the Dabob-Thorndyke sub-basin.

10.3 WATER QUANTITY

10.3.1 Groundwater Quantity

Groundwater recharge estimated for the Dabob-Thorndyke sub-basin is approximately 39,750 af/yr, and averages 14.4 in/yr over the entire area. This relatively high rate of predicted recharge is influenced by relatively high precipitation (averaging 39 in/yr), and a relatively high percent of "outwash" cover (28 percent). Exhibit 6 shows that recharge in non-bedrock areas varies from 10-15 in/yr over glacial till, to 15-25 in/yr in areas without till cover. The amount of precipitation is sufficient to cause significant rejected recharge (runoff) from till covered areas. In places, a portion of this runoff is expected to infiltrate into local outwash/alluvial deposits and supplement recharge to both shallow and principal aquifers. As noted in Chapter 4, recharge is underestimated in a small portion of the Dabob-Thorndyke sub-basin along the eastern coast of the Bolton Peninsula. In this area, the Jefferson County soil survey (SCS 1975) inaccurately reported soils underlain by shallow bedrock. The overall effect on recharge estimated for the entire sub-basin is likely insignificant.

10.3.2 Surface Water Quantity

No surface water quantity information was available for this sub-basin other than that data reported in Section 10.1.1.

10.3.3 Estimate of Water Use and Allocation

10.3.3.1 *Groundwater Use and Allocation*

Exhibit 11 shows the spatial distribution of groundwater use in the Dabob-Thorndyke sub-basin. The total groundwater withdrawal, assuming a domestic use of 250 gpd, is 89 af/yr. Approximately 27 percent of this total use is estimated from water rights and claims for irrigation purposes, and is qualified as being "lower accuracy" data. The remaining 73 percent (65 af/yr) is based on various sources for domestic and commercial uses, and is believed to be relatively high quality data. Given the general reliance on septic systems in the sub-basin, the consumptive portion of these domestic and commercial withdrawals is likely to be much lower than the total amount withdrawn. In the Dabob-Thorndyke sub-basin, 18 groundwater rights have been issued for a total of 491 af/yr. The spatial distribution of groundwater rights is presented in Exhibit 8. Figure 10-2 presents a pie chart of groundwater rights by use and shows that approximately 51 percent of the total allocation is for fish propagation, followed by 46 percent for domestic uses.

Approximately 168 (exempt) single family wells are estimated for the Dabob-Thorndyke sub-basin, translating to a potential exempt allocation of 946 af/yr. However, only a small portion of this exempt allocation is likely to be actually put to use.

There is one groundwater water right application in the Dabob-Thorndyke sub-basin, requesting a Qi of 120 gpm. Exhibit 9 presents the location of this applications, which is for domestic multiple use.

There are 91 groundwater claims in the sub-basin. Table 10-7 lists claims by use, and shows that 27 of these claims list irrigation as a principal use. Typically, only a portion of claims listing irrigation as a

purpose-of-use list numbers of irrigated acres. In the Dabob-Thorndyke sub-basin, water use associated with the reported numbers of irrigated acres amounts to 20 af/yr. If each claim is also assumed to include a domestic use, total claimed groundwater can be estimated at about 101 af/yr. The portion of these claims that have been actually put to use, and would qualify for a water right, is unknown. A map of the distribution of groundwater claims is presented on Exhibit 10.

Table 10-7. Analysis of Surface Water Allocation in Dabob-Thorndyke Sub-basin

Purpose	Percent QI	Percent QA
DM	8%	12%
DS	75%	21%
FR	0%	0%
IR	17%	67%
ST	0%	0%

Explanation of Purpose Codes:

CI	Commercial and Industrial Manufacturing	FS	Fish Propagation
DM	Domestic Multiple	IR	Irrigation
DS	Domestic Single	MI	Mining
MU	Municipal	ST	Stock Watering
FR	Fire Protection		

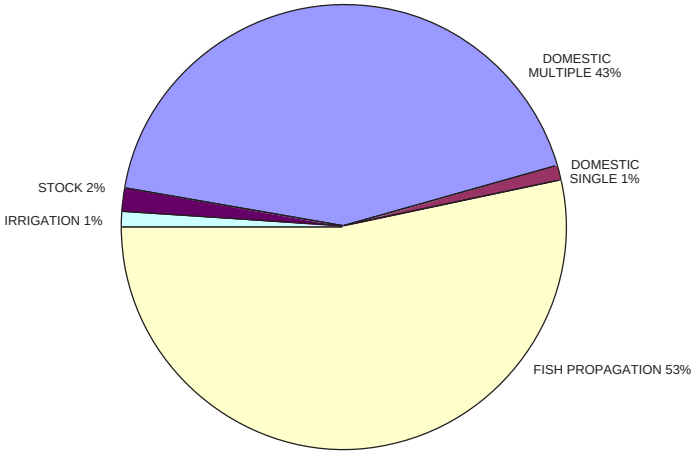
10.3.3.2 *Surface Water Use and Allocation*

Table 10-1 shows the relative distribution of consumptive use surface water rights in the Dabob-Thorndyke sub-basin. The largest use of water is for domestic single use comprising 75 percent of the total instantaneous quantity and 21 percent of the total annual quantity. The next largest use is for irrigation followed by domestic multiple uses. Figure 10-2 presents pie charts of the relative distribution of surface water rights. The total consumptive use rights are 2.31 cfs and 82.59 af/yr annual quantity. Claims data indicate that 2.96 cfs are claimed with an annual quantity estimated at 208 af/yr. The claims data are not reflected on the pie charts. The spatial distribution of surface water rights (Qa), claims (Qi), and claims (Qa) are shown in Exhibits 13, 14, and 15, respectively.

10.4 HYDRAULIC CONTINUITY POTENTIAL

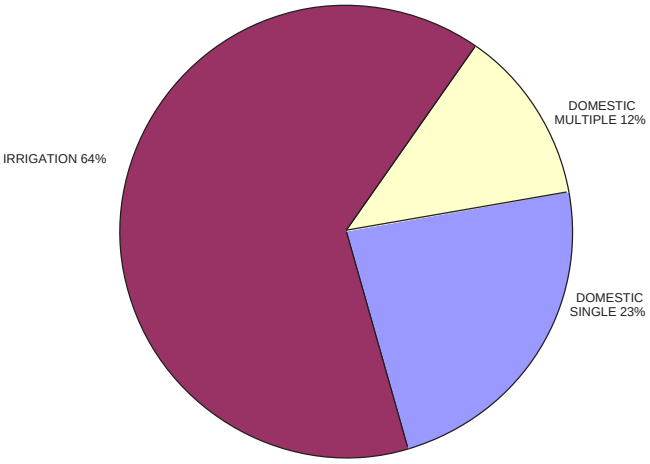
Relative hydraulic continuity potential (RHCP), as shown on Exhibit 17, is ranked as “high” along most of the length of Tarboo Creek. The creek occupies an outwash channel incised into pre-Vashon principal aquifer materials. In a similar fashion, the lower valley of Thorndyke Creek is incised into principal aquifer (Vashon advance outwash) materials and receives a “high” RHCP ranking. Many creeks along the coast of the Toandos Peninsula are also incised into principal aquifer (pre-Vashon) materials, but only one is shown as perennial on USGS topographic maps. Where reaches of streams flow over till-covered areas, they were assigned “low” RHCP rankings.

GROUNDWATER RIGHTS (QA) BY USE



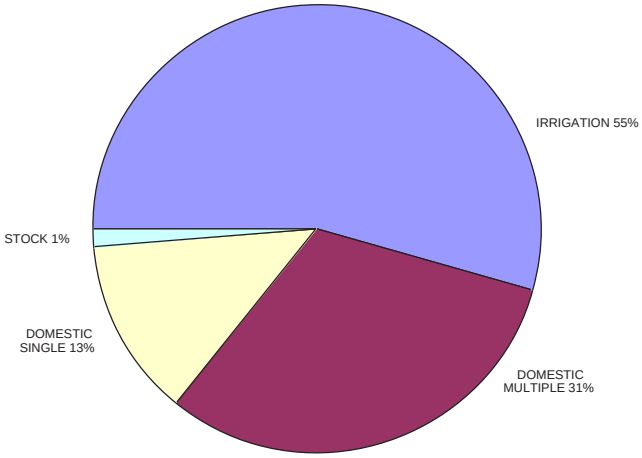
Note: total allocation = 491 af/yr, accounted by use = 452 af/yr, domestic calculated from well logs = 947 af/yr

SURFACE WATER RIGHTS (QA) BY USE



Note: total allocation = 83 af/yr, accounted by purpose 84 af/yr, no non-consumptive rights as Qa

SURFACE WATER RIGHTS (QI) BY USE



Note: total allocation = 6.8 cfs, accounted by purpose = 8.1 cfs, no additional non-consumptive rights as Qi

Source: Ecology WRATs database

Figure 10-2
Dabob-Thorndyke Sub-Basin Groundwater and Surface Water Rights and Use, Consumptive Use Only

10.5 HABITAT

10.5.1 Salmonid Species Present

10.5.1.1 *Tarboo Creek*

Coho salmon, fall chum salmon, steelhead, and cutthroat trout occupy the Dabob-Thorndyke sub-basin. Coho salmon that spawn naturally in this basin, and in adjacent streams such as Donovan Creek, are probably of mixed native and hatchery origin (Lichatowich 1993a; Bahls 1998).

Coho salmon and steelhead access Tarboo Creek up to RM 5.0, and fall chum salmon have been observed spawning near the mouth. Coho salmon are thought to have used the entire mainstem of Tarboo Creek up to RM 7.0 at one time (PNPTC 1997 unpublished data). In Tarboo Creek, below RM 1.1 and in associated tributaries (17.0130 surveyed up to RM 1.1 and a West Fork tributary surveyed up to RM 0.2), up to 30 coho salmon were observed spawning in November and December. The presence of juvenile coho salmon higher up in the Tarboo Creek system suggests that adults may spawn higher than the surveyed reach when flow conditions permit access.

Fall chum salmon have been observed spawning near the mouth of Tarboo Creek (Bahls 1995). Surveys in 1996 – 1997 observed counted 200 chum salmon in the lower half mile, a much larger number than previously seen (Bahls 1997b). These may have been relict native fish, or returns to a Remote Site Incubator that was in place for several years.

Adult chinook salmon were observed in Tarboo Creek in September and October, 1994 and 1996 (Bahls 1995, 1997b) which were, most probably, returns to a private aquaculture facility.

10.5.1.2 *Thorndyke Creek*

Coho salmon and steelhead are present in Thorndyke Creek, though there is some uncertainty over the upper extent of accessible habitat. The most recent surveys assumed that the mainstem was accessible to RM 6.6 (PNTPC 1997 unpublished data), but Lichatowich (1993) reported that they only ascend to RM 4.0. If spawners access the upper reach, juveniles could rear in Sandy Shore Lake. Beaver dams near the mouth are apparently passable when flows increase in the fall. Access to the upper watershed may only be possible at high flow, which could allow juveniles to rear in Sandy Shore Lake. Supplemental surveys of Thorndyke Creek in 1993 – 1995 observed up to nine adult coho salmon between RM 0.5 and RM 1.6 in November and December (Bahls 1994, 1995, 1996). Beaver dams near the mouth of the stream are probably only passable at high flow. Juvenile coho salmon have been observed higher in the drainage, near the confluence of the West Fork, indicating that adults occasionally access the upper reaches. A very few fall chum salmon and steelhead were also observed during these surveys.

10.5.2 Habitat

Tarboo Creek and Thorndyke Creek were assessed by the EDT project (PNPTC 1997 unpublished data) to assess the functionality of habitat with respect to the different life history stages of coho salmon. No other systematic, field assessments of habitat quality have been completed for these streams.

10.5.2.1 *Tarboo Creek*

The channel condition, riparian zone and esturaine zone, for Tarboo Creek is described in the following sections.

Channel Condition

Two reaches of Tarboo Creek were assessed; the mainstem to RM 7.0, and Tributary 17.0130 to RM 3.3. There is a possible blocking culvert at RM 4.2 on the mainstem, at the Center Road crossing. A culvert at RM 2.3 of the mainstem, at Coyle Road, may also be a partial barrier under some flows.

In the mainstem reach spawning and overwinter rearing habitat has been slightly reduced. Aggradation has reduced riffles, and off-channel habitat was eliminated when the reach was channelized to benefit agriculture. Productivity has been dramatically reduced from historic levels for pre-spawning and spawning life stages, due to the lack of habitat diversity, and because a culvert blocks access to the upper reach. Productivity of post-emergent fry has been severely reduced by channelization, because of reduced bank cover and habitat diversity. Incubation success has been reduced by the increased sediment load and channel instability. Summer rearing productivity has been adversely affected by poor riparian condition, increased water temperature, and low flow (PNPTC 1997 unpublished data). Bahls (1992) found that stream temperature at two sites exceeded state standards in August – October, 1992, probably due to lack of riparian cover in agricultural land and along adjacent roads.

The quantity of key habitat has been slightly reduced in the tributary reach. The culvert at the Coyle Road crossing may be a partial barrier to migration. Productivity has been reduced for spawning, incubation, and fry colonization, due to high winter flows, channel instability, and high sediment load . The quality of colonization, and summer and winter rearing habitat has been slightly affected by the decline in habitat diversity (PNPTC 1997 unpublished data). Increased sediment loading may occur due to timber harvest in the upper drainage. Springs in the headwaters of tributary 17.0174 provide year-round stable flow.

Riparian Zone

No information is available describing the quality of riparian habitat in Dabob Creek.

Estuarine Zone

No information is available describing the quality of the estuarine zone at Dabob Creek.

10.5.2.2 *Thorndyke Creek*

The mainstem of Thorndyke Creek up to RM 6.6, the un-named tributary 17.0171 to RM 1.2, and the un-named tributary 17.0174 to RM 0.8, were evaluated for their coho salmon production potential in the EDT study (PNPTC 1997 unpublished data). The drainage is under private ownership, and is subject to sediment loading and other impacts of timber harvest.

Channel Condition

Similar to other independent streams in this area of Hood Canal, streamflow declines markedly in the summer and early fall in Thorndyke Creek (Lichatowich 1993a). Beaver dams near the mouth are passable by coho salmon and steelhead at high flow, but prevent access by chum salmon. Access from the mainstem into Sandy Shore Lake may be possible in years with higher flow. There is no information about the upper watershed, which may dewater in dry years.

However, the overall quality and quantity of habitat in Thorndyke Creek is good (Bahls personal communication 2000). Local residents recall large runs of coho salmon and chum salmon in the 1940's and 1950's, when beaver dams were abundant in the system. The quantity of key habitat is largely unchanged from historic levels. There has been a slight reduction in colonization and winter habitat, due to the loss of off-channel beaver ponds and increased winter flow (PNPTC 1997 unpublished data).

Riparian Zone

No information is available that quantitatively describes the riparian zone of Thorndyke Creek.

Estuarine Zone

The estuary at the mouth of Thorndyke Creek is in excellent condition and has been recommended for acquisition by Pacific Coast Joint Venture. It has also been suggested as a possible study site for the University of Washington Fisheries Research Institute (Lichatowich 1993a).

10.5.3 Restoration Activities

Restoration projects that have been completed in this sub-basin are shown in Table 10-8.

Table 10-8. Summary of Completed Restoration Projects in the Dabob-Thorndyke Sub-basin

Stream	Date	Restoration Type	Description
Tarboo Creek	12/31/1993	Riparian Fencing	Cabler property
Tarboo Creek	9/30/1995	Riparian Fencing	Yarr property
Tarboo Creek	9/30/1995	Riparian Fencing	Edwards property
Tarboo Creek	12/30/1995	Riparian Fencing	Cabler property
Tarboo Creek	6/26/1998	Riparian Fencing	Cabler property
Tarboo Creek	12/31/1998	Riparian Fencing	Yarr Crk
Tarboo Creek	4/30/1996	Riparian Fencing	Radka property
Tarboo Creek	12/30/1992	Salmon Habitat Restoration	Campbell stream restoration project, replaced undesized culvert, and restored 120 ft of channel
Tarboo Creek	12/30/1995	Salmon Habitat Restoration	Radka fish passage construction
Tarboo Creek	12/31/1998	Salmon Habitat Restoration	Yarr Crk stream restoration (completion)
Tarboo Creek	12/30/1995	Streambank Stabilization	Hodge property
Tarboo Creek	4/30/1996	Riparian Planting	Radka property
Tarboo Creek	3/31/1998	Riparian Planting	Cabler property
Tarboo Creek	4/30/1999	Riparian Planting	Yarr Crk riparian planting
East Fork Tarboo Creek	1999	Fish passage	
Thorndyke Creek	9/30/1999	Salmon Habitat Restoration	Replace 3 fish passage barrier culverts
Thorndyke Creek	12/31/1998	Salmon Habitat Restoration	Replace fish passage barrier culvert

Source: JCCD

The following three restoration projects are planned for construction in Dabob-Thorndyke sub-basin during the summer of 2000 or later. Though repair of culvert barriers has been prioritized under recent review processes, the Salmon Recovery Funding Board elected not to fund culvert projects in the early 2000 grant cycle.

- Replace the culvert at Dabob Road on Tarboo Creek to open up 5.1 miles of salmon habitat. This project is funded by WDFD and JCCD and planned for construction in 2001.

- Replace the culvert at Center Road on Tarboo Creek to provide access to upstream salmon habitat. This project is funded by WDFD and JCCD and planned for construction in 2001.

- Replace culvert at Coyle Road on Tarboo Creek to provide access to upstream salmon habitat. This project is funded by Port Gamble S'Klallam Tribe and JCCD and planned for construction in 2000.

10.6 INSTREAM FLOW

Ecology and WDFW (1999) present toe-width study results for Tarboo Creek (RM 0.7) and Thorndyke Creek (RM 1.0). Species and lifestages considered included chinook salmon, coho salmon, chum salmon and steelhead spawning, and steelhead and salmonid juvenile rearing (see Table 6-1). Study results for Tarboo Creek range from a low of 7.1 cfs for salmonid juvenile rearing to a high of 40.4 cfs for chinook salmon and chum salmon spawning. Study results for Thorndyke Creek range from a low of 9.1 cfs for salmonid juvenile rearing to a high of 49.7 cfs for chinook salmon and chum salmon spawning. These results can be used to develop instream flow recommendations for those streams.

Hiss (1993) presents optimum instream flows for Tarboo Creek, East Fork Tarboo Creek, and Thorndyke Creek. Species and lifestages considered were chum salmon, coho salmon and steelhead spawning, and coho salmon and steelhead rearing, as appropriate (see Table 6-3).

10.7 FUTURE PROJECTIONS AND POTENTIAL IMPACTS

10.7.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity

At the time of this writing, the only data available to characterize or predict future changes in land use were the population projections presented in Chapter 1. For several types of land use (e.g. logging and agriculture), the lack of specific information regarding anticipated future changes makes it impossible to predict related impacts to groundwater and surface-water quantities. General discussion of the relationships between these particular land uses, streamflow and groundwater recharge is included in Chapter 4. However, it should be noted that the impacts of such land uses may be highly dependent on particular site characteristics.

The population projections and zoning patterns discussed above, however, can be used to qualitatively predict changes in patterns of residential and associated commercial land use. Increased population requires increased paved surfaces for homes, driveways, roads, and commercial infrastructure. In the Dabob-Thorndyke sub-basin, most of the projected growth is likely to occur in rural residential areas, and thus dense areas of paved surfaces are not expected. As indicated in Chapter 4, little direct data are available regarding the effects of paving on groundwater recharge at typical rural residential densities. While the effects of increased paving in rural residential areas are not expected to be substantial, some reduction in recharge may be associated with conversion of forested lands to meadows and lawns. The effect of population increase on groundwater and surface water withdrawals is presented in Section 10.7.3.

10.7.2 Population Growth

In 1996, the Dabob - Thorndyke sub-basin had 411 residents (Jefferson County 2000). Dabob - Thorndyke sub-basin population growth over the next 20 years is estimated at 185 residents (Jefferson

County 1998). Based on existing zoning (refer to Exhibit 1), the population growth will most likely occur in the lower portion of the Tarboo Creek watershed, and along the shoreline of Tarboo and Dabob Bays.

10.7.2.1 *Potential Impacts of Growth on Water Demand*

Population in the Dabob-Thorndyke sub-basin is expected to increase by 45 percent between 1996 and 2016. Assuming that an average residence contains 2.2 people and uses 250 gpd, the projected increase of 185 people will cause an increased water demand of approximately 24 af/yr. Groundwater is currently the principal source of residential supply for most of the sub-basin, and is predominantly withdrawn by small public water systems and exempt wells. Additional demand will likely be satisfied by similar sources. If additional demand is met with the groundwater resource, estimated current groundwater withdrawals (96 af/yr for residential, commercial and agricultural purposes) would increase by about 25 percent. The increased demand also represents about 0.06 percent of estimated groundwater recharge, with current groundwater withdrawals estimated at 0.24 percent. However, as discussed in Chapter 4, comparison of groundwater pumping with recharge cannot be reliably used as a direct indicator of groundwater availability.

Given the rural nature of the sub-basin, residential reliance on septic systems dictates that the consumptive portion of residential use is significantly less than the total residential groundwater withdrawal. Assuming that 87 percent of residential withdrawals are returned to the ground via septic infiltration (Solly et al. 1993), the actual increase in groundwater consumption would be on the order of 3 af/yr.

10.7.2.2 *Potential Impacts of Growth on Habitat*

Population growth in this sub-basin has projected to grow 45 percent (i.e. an increase of 185) and the resulting development will occur primarily along lower Tarboo Creek and the shoreline of Quilcene and Dabob bays. If further withdrawal of surface water, particularly during the summer months, is constrained, and water use is met from groundwater withdrawal, the increase in population will likely have little impact on streamflow.

High winter streamflow also influences the quality of stream habitat in the Dabob Thorndyke sub-basin. High precipitation and rejected recharge suggests that these streams are naturally “flashy” (i.e., subject to high peak flows and flow fluctuations). This natural condition is mitigated in un-impacted systems by channel sinuosity and complexity and functional floodplains that dissipate the force of high flows. Land use practices in Tarboo Creek have degraded the riparian zone and removed LWD from streams, therefore promoting channel erosion and high sediment loading. New development along Tarboo Creek will tend to exacerbate these problems unless critical area ordinances prevent impacts. This same phenomenon also characterizes Thorndyke Creek, particularly in the middle portion of the mainstem, but the system is affected, overall, to a lesser degree. Rearing habitat in Thorndyke Creek has declined to the loss of beaver ponds (PNPTC 1997 unpublished data). The higher summer flows recorded in Thorndyke Creek (i.e. ^ .95 cfs and 4.90 cfs in July and August, 1993) may in part be attributed to its larger drainage area and the many small lakes in its headwaters that contribute to base flow.

Thorndyke Creek is an example of a small system that maintains relatively high fish production potential, due to low development impact on habitat quality. Its sub-estuary has also been cited as high quality (Lichatowich 1996). Refugia in these un-impacted systems should be the highest priority for habitat protection, as funding is made available for acquisition or development of conservation easements.

Elevated water temperature in Tarboo and Thorndyke creeks during the late summer months affect the habitat of resident juvenile coho salmon, steelhead, and cutthroat. However, water temperature is not

apparently related to lack of forest cover in the riparian zone, as the reaches where these data were collected are forested.

10.7.3 Conservation Options

Water conservation options that may be applicable to water users in the Dabob-Thorndyke Sub-basin are summarized below.

- Tiered Water Rate Structures
- Modification of Landscape Irrigation Practices
- Water Conservation in Water Supply Systems and Individual Homes
- Educational programs
- Water Conservancy Boards To Facilitate Water Rights Transfers

10.8 DATA SYNTHESIS AND INTEGRATION

Groundwater recharge in the Dabob – Thorndyke sub-basin is estimated to be 39,750 af/yr. The total of issued groundwater rights, groundwater claims, and estimated use from exempt wells comprises 3.9 percent of the total recharge. Low summer flow has been identified as a factor that limits coho salmon production in Tarboo Creek and Thorndyke Creek (PNPTC 1997 unpublished data), but if the above estimates are correct, it is unlikely that consumptive use of groundwater has materially influenced streamflow. There are consumptive use rights for surface water totalling 2.31 cfs, and claims of 2.96 cfs. If actual use approaches the claimed volume, it could significantly influence summer low flow. Streamflow is not gaged on either Tarboo Creek or Thorndyke Creek, so the relationship between surface water use and stream discharge is not quantified, but flows of 4.43 cfs and 2.54 cfs were recorded in July and August, 1993, respectively, in Tarboo Creek.

Population growth in this sub-basin has projected to grow 45 percent (i.e. an increase of 185) and the resulting development will occur primarily along lower Tarboo Creek and the shoreline of Quilcene and Dabob bays. If further withdrawal of surface water, particularly during the summer months, is constrained, and water use is met from groundwater withdrawal, the increase in population will likely have little impact on streamflow.

10.9 DATA QUALITY, DATA GAPS AND LIMITATIONS

In addition to the general data gaps identified for the entire WRIA, the following specific data gaps have been identified for this sub-basin:

10.9.1 Water Quality

Data quality and quantity limitations in this sub-basin are consistent with those discussed for the entire WRIA. Specific data gaps for this sub-basin include:

- Conduct mapping along stream corridors to identify potential locations which could be contributing to high temperatures.

10.9.2 Water Quantity

The groundwater quantity data gaps identified for the entire WRIA apply to the Dabob-Thorndyke sub-basin. Additional definition of sub-basin conditions or specific water quantity issues is unavailable to provide increased detail over the WRIA-wide data gaps. Similar to the Dabob-Thorndyke sub-basin, revised definition of soil characteristics on the eastern coast of the Bolton Peninsula, specifically regarding the absence of shallow bedrock, is required to update recharge estimates for this area.

10.9.3 Habitat

- Inventory of high-quality habitat in the Dabob – Thorndyke sub-basin to identify refugia that may complement the extensive habitat restoration and culvert reconstruction projects that have been completed or are planned.

- Scour and deposition studies in lower Tarboo Creek to determine potential effect on egg survival.

- An assessment of the distribution of coho salmon rearing habitat in the upper reaches of Tarboo and Thorndyke creeks, and their tributaries.

10.9.4 In-Stream Flow

Instream flow data gaps for this sub-basin are the same as that identified for the entire WRIA. There is sufficient information to develop instream flow recommendations and to proceed with the setting of instream flows in most of the larger streams in the basin.

11. LUDLOW SUB-BASIN

11.1 SUB-BASIN DESCRIPTION

Encompassing 5 bays and a shallow harbor, the narrow Ludlow sub-basin across much of the eastern extent of WRIA 17 (Figure 11-1). The Ludlow Sub-Basin consists of 23,189 acres and includes Ludlow and Shine Creeks, and Ludlow, Horseshoe, and Teal Lakes. The largest sub- watershed is the 11,085-acre Ludlow Creek watershed that flows into Ludlow Bay. Ludlow Creek consists of a North Fork, a West Fork and small South Fork, which all combine about 1.5 miles from Ludlow Bay (LWMC 1991).

The Oak Bay and Mats Mats Bay watershed covers 4,664 acres. Mats Mats Bay is the major feature of this area and is fed by three small streams. A total of 5,182 acres drains into Squamish Harbor, which is fed by Shine Creek.

11.1.1 Surface Water Features

The sub-basin is primarily drained by a series of small streams directly into Hood Canal. There are 3 significant creeks: Mats Mats Creek, Ludlow Creek, and Shine Creek. A fourth creek drains Teal Lake and flows into Ludlow Bay just southwest of Ludlow Creek. Oak, Paradise and Bywater Bays have very small surface water drainages.

Ludlow Creek has many branches draining the central region of the sub-basin, which comprises 17.3 square miles, and drains into the eastern end of Port Ludlow. The longest branch begins at 200 ft elevation near the Chimacum Valley to the north. Tributaries in the area drain areas up to 500 ft in elevation. The southern tributary drains a series of lakes in the southern highland area, Ludlow Lake, Horseshoe Lake and two other unnamed lakes that are all at elevations of approximately 500 ft. The total length of the Ludlow Creek branches is 10 plus miles. They converge at RM 1.5 of the mainstem.

Miscellaneous streamflow measurements taken on Ludlow Creek by the USGS were reported in the DQ Plan. Those measurements were 4.96 and 2.87 cfs in July and August of 1993, respectively. Teal Lake is located south of the southern shoreline of Port Ludlow at an elevation of approximately 400 ft. There is no mapped surface outlet, however it is believed that ground-water discharges into several unnamed streams which drain north into Port Ludlow and east into Hood Canal.

Mats Mats Creek is a short, shallow drainage emptying into the northwest part of Mats Mats Bay that drains an area of 7.3 square miles.

Shine Creek, which drains a basin of 5.2 square miles, is 2 plus miles in length and empties into a mudflat and marsh on Squamish Harbor. The headwaters of the creek are at an elevation of 150 ft and located 2 miles south of Port Ludlow. Miscellaneous streamflow measurements taken on Shine Creek by the USGS were reported in the DQ Plan. Those measurements were 0.64 and 1.23 cfs in July and August of 1993, respectively. Surface water features for the Ludlow sub-basin are summarized in Table 11-1.

11.1.2 Groundwater Features

Hydrogeologic characterization for the Ludlow sub-basin includes existing mapping of surficial geology, several generalized geologic cross-sections (PGG and EES 1994), mapping of miscellaneous groundwater elevations (Grimstad and Carson 1981), relatively detailed hydrogeologic analysis of the Port Ludlow/Shine area (Robinson and Noble 1992), and limited discussion of potential well yields (PGG and EES 1994 and Grimstad and Carson 1981). The sub-basin is characterized by extensive areas covered

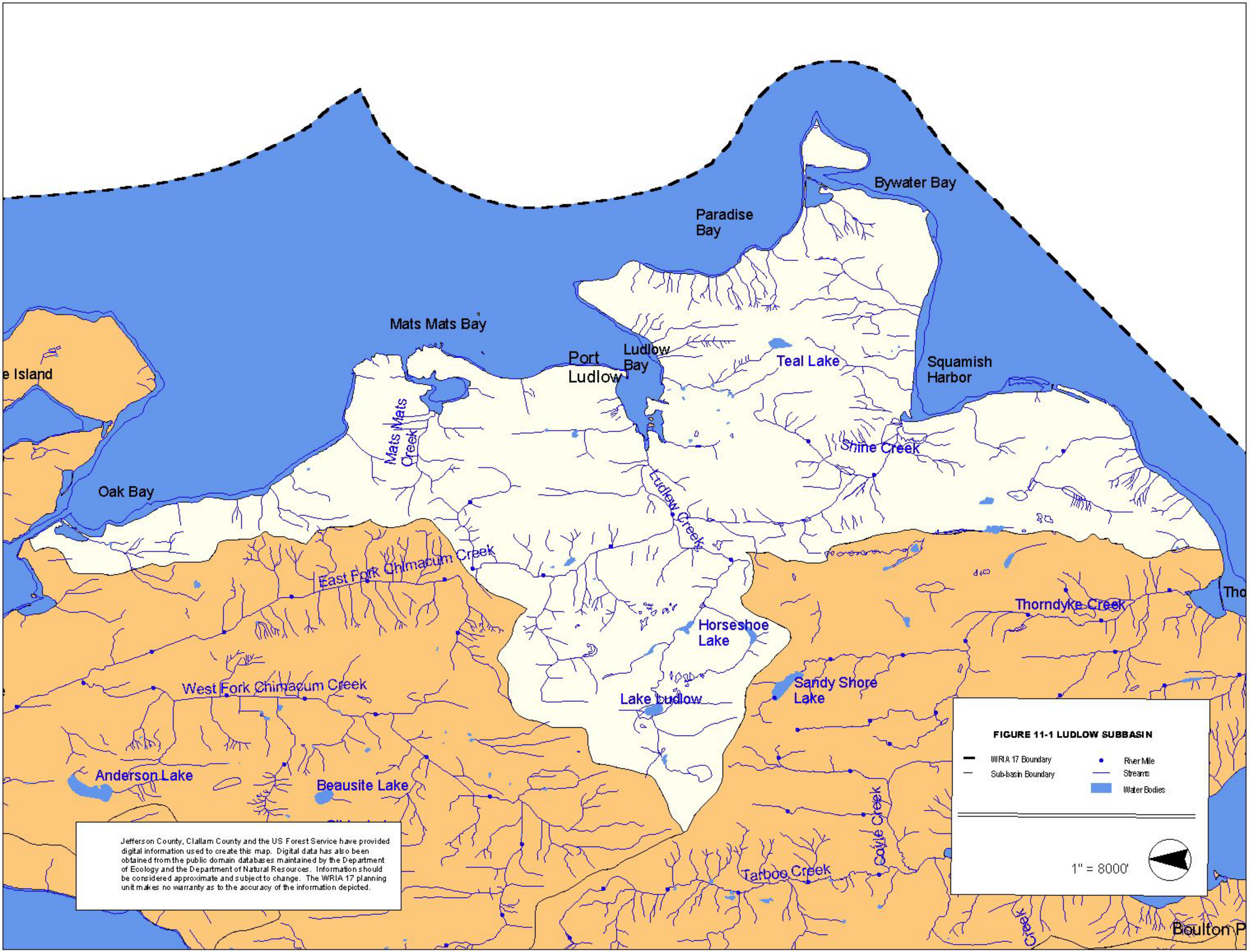

Bywater Bay
Paradise Bay
Mats Mats Bay
Port Ludlow
Ludlow Bay
Teal Lake
Squamish Harbor
e Island
Mats Mats Creek
Shine Creek
Oak Bay
Ludlow Creek
East Fork Chimacum Creek
Thorndyke Creek
Tho
Horseshoe Lake
West Fork Chimacum Creek
Sandy Shore Lake
Lake Ludlow
Anderson Lake
Beausite Lake
Coyle Creek
Tarboo Creek
Boulton P
FIGURE 11-1 LUDLOW SUBBASIN
WRIA 17 Boundary
Sub-basin Boundary
River Mile
Streams
Water Bodies
1" = 8000'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.

Table 11-1. Fresh Water Features in the Ludlow Sub-basin

Main Water Feature	Tributary	Confluence	Ecology Class
Mats Mats Creek			Class AA
Ludlow Creek			Class AA
	North, West, and South forks	RM 1.5	Class AA
Shine Creek			Class AA
	Northeast fork and Northwest fork	RM 2.0	Class AA

Source: LWMC (1991)

with glacial till, by channels eroded through the till into underlying principal aquifer materials, and by the presence of shallow bedrock. Generalized surficial geology for the Ludlow sub-basin can be seen on Exhibit 17. Principal aquifer materials in the Port Ludlow and Shine areas are composed of pre-Vashon stratified glacial drift and interglacial deposits (Robinson and Noble 1992). In addition, Vashon advance outwash materials may be saturated in places. Exposures of principal aquifer materials are noted along the incised channels. Recessional outwash and alluvial materials have subsequently filled in portions of the channels. A large bedrock body is noted south of Ludlow Bay, and underlies the principal aquifer between Ludlow Bay and Squamish Harbor at elevations ranging from land surface to several hundred feet below sea level (Robinson and Noble 1992). The bedrock is composed of basalt, and is also observed along the coast at Mats Mats Bay. Wells are completed in this basalt in the Shine area, and likely other locations where the rock produces water. In contrast, bedrock of sedimentary origin is observed along the coast at Oak Bay. Potential well yields vary from high to low in unconsolidated deposits, and are typically lower in the volcanic bedrock.

11.1.3 Land Use

The Ludlow sub-basin consists of 38 square miles, about 97 percent of which is commercial forest land. The largest drainage is the Ludlow Creek watershed, which comprises over 17 square miles. The Oak Bay and Mats Mats Bay watershed covers 7 square miles. The majority of forest land in the sub-basin is owned by Pope Resources. Two percent of the land is in agricultural use, primarily for livestock grazing. Residential lands comprise approximately 41 percent of the sub-basin with the primary residential land use of one dwelling unit per five acres. The Ludlow Bay community comprises one percent of the sub-basin, but includes the highest population density. Existing land use in this sub-basin is shown in Table 11-2.

11.2 WATER QUALITY

11.2.1 Surface Water Quality

Freshwater data sources for the Ludlow sub-basin are summarized in Table 11-3.

Water quality for eight streams flowing into Ludlow Bay has been monitored for over six to eight consecutive years of sampling. Water quality has been relatively consistent over time, with no identifiable long-term trends upward or downward (Berryman and Henigar/Vasey Engineering 1998). The geometric mean of FC is typically 8-9/100mL at most marine stations, and 15-18 /100mL for Ludlow Creek, Salt Marsh Creek, and Ludlow Road culvert. In Ludlow Bay tributaries, DO levels are below the state water quality standards at base flow, but pH remained within the acceptable range (Berryman and Henigar/Vasey Engineering 1998).

Table 11-2. Ludlow Sub-basin Land Use

Description	No. of Parcels	Acres	% of Total
Single Family Tracks	26	112	0.5%
Rural Residential (1:5)	3,114	3,951	16.3%
Rural Residential (1:10)	70	657	2.7%
Rural Residential (1:20)	205	3,923	16.2%
Single Family (4:1)	1,797	1,246	5.1%
Multiple Family (10:1)	47	74	0.3%
Resort Complex (10:1)	101	51	0.2%
Parks, Preserves, Recreation	26	231	1.0%
Open Space Reserve	12	356	1.5%
Rural Forest	44	1,080	4.5%
Commercial Forest	156	11,120	45.9%
Inholding Forest	8	100	0.4%
Village Business District	13	37	0.2%
Commercial Agriculture	8	122	0.5%
Water and Tidelands	192	303	1.3%
Roads and Right of Ways	273	851	3.5%
Totals	**6,092**	**24,214**	**100.0%**

Source: Jefferson County (2000)

Table 11-3. Surface Water Quality Data Available for the Ludlow Sub-basin

Survey Areas	Parameters					Years Sampled	Sample Locations	Reference
	Temp.	DO	Turb	pH	FC			
Mats Mats Bay Tribs (three)		X			X	1989	3	Smayda and Harper (1989), as seen in LWMC (1991)
Mats Mats Bay Tribs (three)					X	1988	4	Rubida (1989) as seen in LWMC (1991)
Mats Mats Bay Tribs (three)	p		p		X	1991 - 1992	3	LWMC (1991), Gately (1993a)
Ludlow Creek					p	1988	3	Rubida (1989) as seen in LWMC (1991)
Ludlow Creek	p		p		X	1991 - 1992	3	LWMC (1991), Gately (1993a)
Ludlow Bay tributaries	X	X		p	p	1984 - 1997	8	Berryman and Henigar/ Vasey Engineering (1998)
Shine Creek	p		p		X	1991 - 1992	1	LWMC (1991), Gately (1993a)

X = water quality was exceeded for at least one sample

p = no water quality criteria was exceeded

Freshwater draining into Mats Mats Bay exceeded the state standard at times in 1988 and 1989 (Rubida 1989; Smayda and Harper 1989, as seen in LWMC 1991) and in 1991 (LWMC 1991; Gately 1993a). However, these streams are not currently listed on the 303(d) list, therefore this is probably a historical condition. Levels of FC in Ludlow Creek and Shine Creek have generally been below the state standard (LWMC 1991).

A single tributary of Bywater Bay was monitored twice during storm events and all parameters passed state standards (Gately 1993a) Paradise Bay tributaries were sampled twice during storm events and did not meet the state standard for FC (Gately 1993a).

11.2.2 Marine Water

Marine water data sources for the Ludlow sub-basin are summarized in Table 11-4.

Table 11-4 WRIA 17 Ludlow Sub-basin Marine Water Quality Data Available

Survey Areas	Parameters			Years Sampled	Sample Locations	Reference
	Temp	DO	FC			
Mats Mats Bay			X	1988	4	Rubida 1989 as seen in LWMC (1991)
Mats Mats Bay	p	X	p	1989	4	Smayda and Harper (1989), as seen in LWMC (1991)
Ludlow Bay		X		1985	1	Patmont et al. (1985) as seen in LWMC (1991)
Ludlow Bay			X	1988	4	Rubida (1989) as seen in LWMC (1991)

X = water quality was exceeded for at least one sample

p = no water quality criteria was exceeded (passed)

Dissolved oxygen in Mats Mats and Ludlow Bays is depressed in the fall because of upwelling from Admiralty Inlet as well as decomposition of logs in the log storage area of Ludlow Bay (LWMC 1991). Marine water quality data collected by DOH for this sub-basin is summarized in Table 11-5. FC levels in Bywater Bay, Squamish Harbor, and Oak Bay are well below the state standard.

Table 11-5 Fecal Coliform Monitoring Results in Port Ludlow for 1994-1998

Station	Sub-Basin	No. Of Samples	Range	Geometric Mean	Meets Standard
1	Bywater Bay	30	1.7-4.5	1.8	Yes
2	Bywater Bay	30	1.7-2.0	1.7	Yes
3	Bywater Bay	30	1.7-4.5	1.7	Yes
4	Squamish Harbor	31	1.7-4.5	1.8	Yes
5	Squamish Harbor	30	1.7-7.8	1.8	Yes
6	Squamish Harbor	32	1.7-33.0	2.3	Yes
7	Squamish Harbor	31	1.7-22.0	2.0	Yes
8	Squamish Harbor	31	1.7-4.5	1.7	Yes
9	Squamish Harbor	31	1.7-11.0	2.0	Yes
10	Squamish Harbor	31	1.7-17.0	2.0	Yes
10	Oak Bay	30	1.7-4.5	1.8	Yes
11	Oak Bay	30	1.7-17.0	2.2	Yes
12	Oak Bay	30	1.7-23.0	1.9	Yes
13	Oak Bay	30	1.7-2.0	1.7	Yes
14	Oak Bay	30	1.7-4.5	1.7	Yes
15	Oak Bay	30	1.7-2.0	1.7	Yes
16	Oak Bay	7	1.7-11.0	2.2	N/A
17	Oak Bay	5	1.7-1.0	1.7	N/A

Source: DOH (1999a)

Table 11-5 Fecal Coliform Monitoring Results in Port Ludlow for 1994-1998 (continued)

N/A –Criteria require a minimum of 30 samples from each station.

Ludlow Bay FC levels have generally not exceeded the state standard. However, Ludlow Creek and boater wastewater discharges have been shown to contribute substantially at times when FC are elevated (LWMC 1991).

DOH sampled three stations in Bywater Bay from 1988-1992 and met the state standard (Unpublished data referenced in Gately 1993a). DOH sampled seven stations in Squamish Harbor from 1988 – 1992 under the ambient monitoring program and were all within the state standard (unpublished data referenced in Gately 1993a).

In October 1992, 367 acres were approved for commercial shellfish growing in Oak Bay. In 1992, 15 acres were approved for commercial growing in Mats Mats Bay. Shellfish are also grown commercially in the middle of Bywater Bay (Gately 1993a). Shellfish in Mats Mats Bay have been periodically contaminated with FC bacteria, exceeding regulations for commercial shellfish harvest in 1989 (Smayda and Harper 1989 as seen in Gately 1993a).

11.2.3 Inventory of Potential Surface Water Contaminant Sources

11.2.3.1 *Point Sources*

Point sources, each with an individual NPDES permit are summarized below from Ecology (1999a):

- Hansen Dam Jefferson County
- Port Ludlow Marina
- Port Ludlow STP
- USWCOM Port Ludlow Company
- Lone star NW, Inc. Mats Mats Quarry
- Fletcher General Construction Company Mats Mats Quarry
- Witter Dam
- Port Ludlow Log Yard
- USWCOM Port Ludlow Pe32593
- Cliff Larrance Shine Quarry
- WA DOT PIT Y88
- Fred Hill Materials Shine Pit
- Jefferson County PW Shine Pit

It is noted that NPDES point source locations have been provided by Ecology and in some cases may depict facility names and locations that may not be entirely representative of existing conditions. The Ecology database does also not distinguish between stormwater and/or wastewater permits. No specific monitoring data or compliance problems were available for these specific point sources.

11.2.3.2 *Non-Point Sources*

General non-point sources in the Ludlow sub-basin are summarized in Table 11-6.

Table 11-6. Summary of Non-Point Source Pollution in the Ludlow Sub-Basin

Location	Description of Pollutant
Shine Creek drainage	Clearcutting causing erosion, debris, higher temperatures, and chemicals
Ludlow Watershed	Runoff/erosion/stormwater from residential areas and agricultural lands
Ludlow Bay and Mats Mats Bay	Boats and Marinas docking in the harbors contribute to FC by discharging wastes into the water.

Source: LWMC (1991)

11.2.4 Summary of Surface Water Trends and Compliance Problems

None of the streams or bays in this sub-basin are on the 303(d) list for 1996 or 1998. However, previous studies have identified the following potential problems in the Ludlow sub-basin:

- FC counts have been elevated in the streams from time to time. However, none of the streams are listed on the 303(d) list and no long-term trends are evident for water quality data for Ludlow Bay tributaries. Concentrations of most parameters (FC, nutrients, and metals) are elevated during storm events, and lower during summer base flow monitoring (Berryman and Henigar/Vasey Engineering 1998).

- Ludlow Bay has generally met the state standard (Gately 1993a). Ludlow Bay water quality criteria for turbidity and FC may be exceeded occasionally in the immediate vicinity of tributary outfalls (Berryman and Henigar/Vasey Engineering 1998).

- Shine Creek has shown increasing impacts such as sedimentation originating from logging unstable soils which had smothered a large area of salmon spawning habitat (LWMC 1991).

11.2.5 Groundwater Quality

Chloride concentrations in the Ludlow Sub-Basin are mapped on Exhibit 4, and show a relatively "spotty" distribution of saltwater intrusion problems. Elevated concentrations are observed in small clusters along Oak Bay and Mats Mats Bay, and along the coastline between Bywater Bay and areas south of Squamish Harbor. Isolated instances of elevated chloride are observed on a small peninsula on the south side of Ludlow Bay and at Oak Point. In some cases, wells with elevated chloride occur near other wells with concentrations at or near background. This variability of chloride occurrence may be due to differing rates of groundwater withdrawal or may reflect the complexity of the groundwater flow system – with different aquifers or water-bearing zones being more or less susceptible to intrusion. In contrast to coastal wells, none of the inland wells in the Ludlow Sub-Basin showed evidence of elevated chloride.

Forbes and CH2M Hill (1993) compared chloride concentrations measured in 1978 and 1983 for three wells in the Ludlow Sub-Basin. One of these wells, located in Bywater Bay, increased from 250 to 410 mg/l chloride. The other two, located in Mats-Mats and Oak Bay, were both below 20 mg/l and showed no significant change.

Nitrate concentrations in the Ludlow Sub-Basin are mapped on Exhibit 5. The distribution of wells showing elevated nitrate concentrations is "spotty" within the sub-basin. Four wells are noted which show nitrate concentrations between 2 and 5 mg/l, two of which occur close together on the south side of Ludlow Bay. The majority of measured nitrate concentrations are within the natural background range (≤

1 mg/l), however isolated instances of mildly elevated nitrate concentration (1-2 mg/l) are scattered within the sub-basin. In general, the Ludlow Sub-Basin shows very little impact from nitrogen contamination. Groundwater contamination has been diagnosed from a leaking underground storage tank at the Port Ludlow Golf Course. Cleanup has been initiated at the site, and the site is not listed as groundwater contamination that affects drinking water (Ecology and WDOH 1999).

11.3 WATER QUANTITY

11.3.1 Groundwater Quantity

Groundwater recharge estimated for the Ludlow sub-basin is approximately 21,200 af/yr, and averages 10.0 in/yr over the entire area. Exhibit 6 shows that recharge in non-bedrock areas varies from 5-15 in/yr over glacial till, to 15-20 in/yr in areas without till cover. Recharge through till can be less than 12 in/yr in the northern areas of the sub-basin, where precipitation minus plant evapotranspiration does not exceed the transmitting capacity of the till. Approximately 10 percent of the sub-basin is covered by shallow bedrock, and is assumed to have low rates of recharge. Precipitation averages 30 in/yr over the sub-basin, and is likely to cause rejected recharge (i.e. runoff) in the southern portion of the sub-basin where precipitation is slightly higher. In places, a portion of this runoff is expected to infiltrate into local outwash/alluvial deposits and supplement recharge to the principal aquifers.

11.3.2 Surface Water Quantity

No surface water quantity information was available for this sub-basin other than that data reported in Section 11.1.2.

11.3.3 Estimate of Water Use and Allocation

11.3.3.1 *Groundwater Use and Allocation*

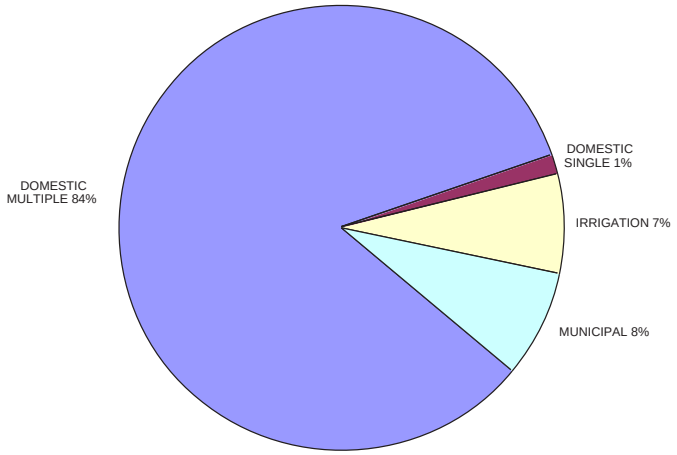
Exhibit 11 shows the spatial distribution of groundwater use in the Ludlow sub-basin. The total groundwater withdrawal, assuming a domestic use of 250 gpd, is 1,395 af/yr. Approximately 68 percent of this total use is estimated from water rights and claims for irrigation purposes, and is qualified as being "lower accuracy" data. The remaining 32 percent (447 af/yr) is based on various sources for domestic and commercial uses, and is believed to be relatively high quality data. The *consumptive* portion of domestic and commercial groundwater use is likely to be somewhat lower due to areas where households in the sub-basin use septic systems. However, the Port Ludlow community uses wastewater treatment for approximately 1000 homes and the resort facilities and discharges treated water to Ludlow Bay.

In the Ludlow sub-basin, 47 groundwater rights have been issued for a total of 1,407 af/yr. The spatial distribution of groundwater rights is presented in Exhibit 8. Figure 11-2 presents a pie chart of groundwater rights by use and shows that approximately 92 percent of the total allocation is for municipal or domestic multiple use, followed by 7 percent for irrigation

Approximately 488 (exempt) single family wells are estimated for the Ludlow sub-basin, translating to a potential exempt allocation of 2,731 af/yr. However, only a small portion of this exempt allocation is likely to be actually put to use.

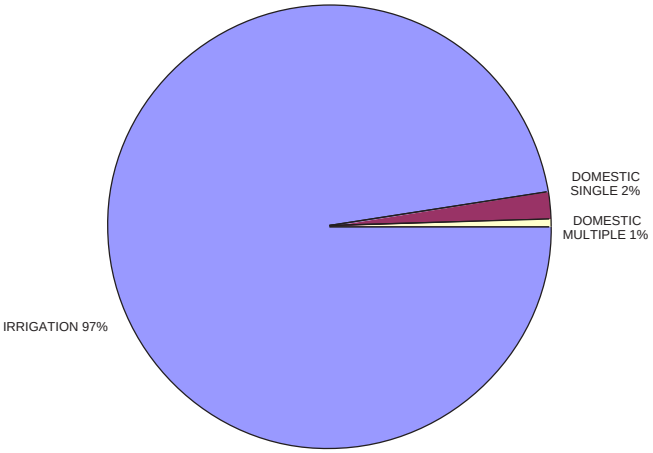
There are six water right applications in the Ludlow sub-basin, requesting a total Qi of 473 gpm. Exhibit 9 presents the locations of these applications, and Table 4-2 lists their stated purpose of use. Purposes include domestic multiple, domestic single, mining and commercial and industrial.

GROUNDWATER RIGHTS (QA) BY USE



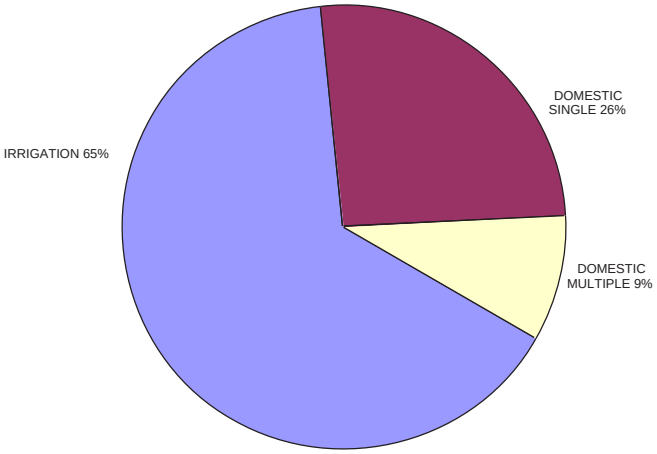
Note: total allocation = 1407 af/yr, accounted by use = 1157 af/yr, domestic exempt wells = 2731 af/yr

SURFACE WATER RIGHTS (QA) BY USE



Note: total allocation = 582 af/yr, accounted by purpose 569 af/yr, no additional non-consumptive rights as Qa

SURFACE WATER RIGHTS (QI) BY USE



Note: total allocation = 3.6 cfs, accounted by purpose = 5.0 cfs, additional non-consumptive rights = 5.6 cfs

Source: Ecology WRATs database

Figure 11-2
Ludlow Sub-Basin Groundwater and Surface Water Rights and Use, Consumptive Use Only

There are 311 groundwater claims in the sub-basin. Table 4-3 lists claims by use, and shows that 71 of these claims list irrigation as a principal use. Typically, only a portion of claims listing irrigation as a purpose-of-use list numbers of irrigated acres. In the Ludlow sub-basin, water use associated with the reported numbers of irrigated acres amounts to 864 af/yr. If each claim is also assumed to include a domestic use, total claimed groundwater can be estimated at about 1,175 af/yr. The portion of these claims that have been actually put to use, and would qualify for a water right, is unknown. A map of the distribution of groundwater claims is presented on Exhibit 10.

11.3.3.2 *Surface Water Use and Allocation*

Table 11-7 shows the relative distribution of consumptive use surface water rights in the Ludlow sub-basin. The largest use of water is for irrigation, comprising 65 percent of the total instantaneous quantity and 97 percent of the total annual quantity. The next largest use is for domestic single use, followed by domestic multiple uses. Figure 11-2 presents pie charts of the relative distribution of surface water rights. The total consumptive use rights are 3.56 cfs and 581.9 af/yr annual quantity. Claims data indicate that 26.5 cfs are claimed with an annual quantity estimated at 151.5 af/yr. The claims data is not reflected on the pie charts. One claim is for 25 cfs, which is believed to be spurious because streamflow in Ludlow Creek is not likely to meet that level. The spatial distribution of surface water rights (Qa), claims (Qi), and claims (Qa) are shown in Exhibits 12, 13, and 14, respectively.

Table 11-7. Analysis of Surface Water Allocation in Ludlow Sub-basin

Purpose	Percent Qi	Percent Qa
DM	9%	1%
DS	26%	2%
FR	0%	0%
IR	65%	97%
ST	0%	0%

Explanation of Purpose Codes:

CI	Commercial and Industrial Manufacturing	FS	Fish Propagation
DM	Domestic Multiple	IR	Irrigation
DS	Domestic Single	MI	Mining
MU	Municipal	ST	Stock Watering
FR	Fire Protection		

11.3.4 Hydraulic Continuity Potential

Relative hydraulic continuity potential (RHCP), as shown on Exhibit 17, is ranked as “high” along most streams in the Ludlow sub-basin. This ranking is assigned because the stream valley has cut downward through the till into principal aquifer materials. On the upper reaches of Ludlow Creek, RHCP is ranked as “medium-high” because lower-permeability bog deposits in the valley bottom are likely reduce the hydraulic connection between the principal aquifer and the stream. RCHP is marked as “medium” where outwash and alluvial deposits overlie till, and “low” where streams cross till covered areas. Streams shown as ephemeral on USGS topographic maps are ranked as if they were perennial, but are indicated with a dotted line to distinguish them from flowing streams.

11.4 HABITAT

11.4.1 Salmonid Species Present

Supplemental escapement surveys have described the distribution of coho salmon and other species in Shine Creek. During surveys of RM 0.3 – 0.8 in Shine Creek in 1992 – 1995, Bahls (1993, 1994, and 1995) observed up to 16 adult coho salmon spawning. Unusually late-spawning coho salmon were observed in January, 1997 (Bahls 1997b). Fall chum salmon were not seen during these surveys, but coastal cutthroat were present in late January and early February, 1993. Additional surveys of small tributary streams below Highway 104 observed up to 13 coho salmon in one stream, and 19 in another. Scales collected from two adults suggested that they were reared in net pens. Beaver dams present in the lower reaches are apparently passable by coho salmon during high flow because juvenile coho salmon were observed above the dams during the following summer. Beaver ponds and wetland in the Shine Creek drainage provide suitable winter rearing habitat, and so the potential for increasing production of coho salmon, and possibly cutthroat and steelhead, is still high (PNPTC 1997 unpublished data).

11.4.1.1 *Shine Creek*

Juvenile chinook salmon were observed in Shine Creek, which were probably vagrants from other systems. Use by other than local fish stocks points to the importance of these small streams in providing regional habitat integrity (Lichatowich 1993a).

A small number of coho salmon and chum salmon also still spawn in the lower reaches (up to RM 0.2) of Ludlow Creek. Up to three coho salmon and five chum salmon were observed during surveys conducted in 1992 – 1995 (Bahls 1994 1995, 1996). During the winter of 1993 – 1994, beaver ponds flooded about half of the usable spawning habitat below the impassable falls.

Coho salmon that are produced naturally in the small independent streams in northern Hood Canal (i.e.) are accounted and managed as a single unit (see Section 2.2.2). Estimates of total spawning escapement to these individual streams are not made.

11.4.1.2 *Ludlow Creek*

Ludlow Creek runs approximately four miles from it headwaters to Port Ludlow, but anadromous fish access above RM 0.5 is restricted by a natural falls barrier (Williams et al.1975). Small number of coho salmon and fall chum salmon currently spawn in this lower section, and it is likely that resident cutthroat are present above the falls (LWMC 1991).

11.4.2 Habitat Assessment

11.4.2.1 *Channel Condition*

Coho salmon habitat quality was assessed in Shine Creek, from the mouth to RM 3.0 (PNPTC 1997 unpublished data). The quantity of habitat below RM 1.1 and above 1.8 has been reduced slightly, affecting adult access, and the productivity of spawning and summer rearing habitat. In some higher reaches habitat is comparable to historic conditions. The quantity of habitat in the lower mainstem is greater than other similar streams due to the colonization and wintering habitat provided by beaver ponds. This concurs with a survey by Jefferson County which noted potentially productive habitat for coho salmon and cutthroat in the extensive wetlands and beaver ponds (Lichatowich 1993a). The quality of

spawning habitat has been reduced in the lower mainstem due to increased sediment load. High winter flow in the upper mainstem, due to lack of habitat diversity and channelization of the stream, has reduced the quality of colonization habitat.

11.4.2.2 *Riparian Zone*

There is no information that systematically describes the riparian zone of Shine Creek or Ludlow Creek.

11.4.2.3 *Estuarine Zone*

The estuary is isolated from Hood Canal by filling at South Point Road, but there is potential to re-establish connection to allow mixing of salt and freshwater, and to restore estuarine function.

11.4.3 Restoration Activities

Restoration activities in this sub-basin are summarized in Table 11-8.

Table 11-8. Summary of Completed Restoration Projects in the Ludlow Sub-basin

Stream	Date	Restoration Type	Description
Unnamed Creek of Oak Bay	ND	Culvert Replacement	Replaced undersized culvert at Hiller Road

Source: JCCD

No restoration projects are planned for construction in the Ludlow sub-basin.

11.5 INSTREAM FLOW

Ecology and WDFW (1999) present toe-width study results for Ludlow Creek (RM 0.5) and an unnamed Mats Mats Bay tributary (17.0200) (RM 0.2). Species and lifestages considered included chinook salmon, coho salmon, chum salmon and steelhead spawning, and steelhead and salmonid juvenile rearing (see Table 7-1). Study results for Ludlow Creek range from a low of 12.1 cfs for salmonid juvenile rearing to a high of 63.9 cfs for chinook salmon and chum salmon spawning. Study results for the unnamed Mats Mats Bay tributary range from a low of 1.8 cfs for salmonid juvenile rearing to a high of 12.5 cfs for chinook salmon and chum salmon spawning. These results can be used to develop instream flow recommendations for those streams.

Hiss (1993) presents optimum instream flows for Ludlow Creek, Shine Creek, and an unnamed Mats Mats Bay tributary (17.0200). Species and lifestages considered were chum salmon, coho salmon and steelhead spawning, and coho salmon and steelhead rearing, as appropriate. East Squamish Creek (17.0183) was determined to have no suitable measurement site (see Table 6-3).

11.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS

11.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity

At the time of this writing, the only data available to characterize or predict future changes in land use were the population projections presented in Chapter 1. For several types of land use (e.g. logging and agriculture), the lack of specific information regarding anticipated future changes makes it impossible to

predict related impacts to groundwater and surface-water quantities. General discussion of the relationships between these particular land uses, streamflow and groundwater recharge is included in Chapter 4. However, it should be noted that the impacts of such land uses may be highly dependent on particular site characteristics.

The population projections and zoning patterns discussed above, however, can be used to qualitatively predict changes in patterns of residential and associated commercial land use. Increased population requires increased paved surfaces for homes, driveways, roads, and commercial infrastructure. In the Ludlow sub-basin, about 80 percent of the projected growth is projected to occur in the Ludlow Master Planned Resort. Unless sufficient stormwater management practices are applied in this area, suburban densities are likely to increase runoff and reduce groundwater recharge. In the rural residential portions of the Ludlow sub-basin, the effects of associated densities of impervious surfaces are not expected to substantially reduce recharge. However, some reduction in recharge may be associated with conversion of forested lands to meadows and lawns. The effect of population increase on groundwater and surface water withdrawals is presented in section 11.6.3.

11.6.2 Sub-basin Population Growth

In 1996, the Ludlow sub-basin had 2,882 residents (Jefferson County 2000). Ludlow sub-basin population growth over the next 20 years is estimated at 3,489 people (Jefferson County 1998). Based on existing zoning (refer to Exhibit 1), the population growth will most likely occur in the resort community of Port Ludlow and along shoreline areas near Bywater Bay, Mats Mats Bay, Oak Bay and Squamish Harbor.

11.6.3 Potential Impacts of Growth on Water Demand

Population in the Ludlow sub-basin is expected to increase by 121 percent between 1996 and 2016. Assuming that an average residence contains 2.2 people and uses 250 gpd, the projected increase of 3,489 people will cause an increased water demand of approximately 444 af/yr. Groundwater is currently the principal source of residential supply for most of the sub-basin, with uses met by both larger purveyors (e.g. at Port Ludlow) and a combination of small public water systems and exempt wells. Given projected patterns of population growth in the sub-basin, most of the additional demand will need to be met by the Port Ludlow water system. If all of the additional demand is met with groundwater, estimated current pumping withdrawals (702 af/yr for residential, commercial and agricultural purposes) would increase by about 63 percent. The increased demand also represents about 2.1 percent of estimated groundwater recharge (Table 4-2), with current groundwater withdrawals estimated at 3.3 percent. However, as discussed in Chapter 4, comparison of groundwater pumping with recharge cannot be reliably used as a direct indicator of groundwater availability.

The community of Port Ludlow currently treats domestic wastewater and discharges the effluent into the bay. The additional water use associated with Port Ludlow will therefore be almost entirely consumptive, and additional use for the sub-basin as a whole will be predominantly consumptive. In the portions of the sub-basin zoned as rural residential, reliance on septic systems dictates that the water use associated with additional development will be largely non-consumptive.

11.6.4 Potential Impacts of Growth on Habitat

The effects of population growth on stream and riparian habitat in the Ludlow sub-basin are of concern, primarily, in the Shine Creek and Ludlow Creek drainages, which are the principle fish-bearing streams. With high growth projected through 2016 in the Port Ludlow community,

consumptive use of groundwater is certain to rise unless water is imported from outside the basin. Current estimates of groundwater use in the Ludlow sub-basin range up to 683 af/yr, which is only 3 percent of the estimated annual recharge in the sub-basin. Low summer flows have not been identified as limiting factors for fish production in either Shine Creek or Ludlow Creek. However, further groundwater development in the upper reaches of Shine Creek could influence base flow, because of high potential hydraulic continuity in the upper basin.

Of greater concern with respect to fish habitat integrity is maintenance of forest and vegetative cover in existing riparian buffer zones, and restoring impacted riparian zones to the extent possible. Low residential density and conservative land-use practices must be promulgated to protect these stream buffers, and reduce the potential for erosive sediment loading from adjacent lands and stream crossings. Beaver ponds and wetlands provide essential winter rearing habitat in the lower Shine basin, so these critical areas must also be protected from the impacts of development. Anadromous salmonid use is restricted to a 0.5 mile reach in lower Ludlow Creek. However, protection of stream channel and riparian integrity in the upper watershed are necessary to maintain the productivity of that lower reach, as well as resident salmonid habitat in the upper drainage.

With growth projected to concentrate along the marine shoreline in this sub-basin, it will be important to maintain the integrity of the littoral zone and the small sub-estuaries at the mouths of Shine Creek, Ludlow Creek, and other streams. There is also need to restore the sub-estuarine connection at the mouth of Shine Creek. If these objectives are accomplished, Shine Creek can be another example of restoring and maintaining fish productivity in a moderately developed basin. This shoreline is an important migratory corridor for juvenile salmon produced in more southerly Hood Canal stream systems, which lend credence to restoration and protection initiatives beyond the context of the current limited salmonid production in local streams.

11.6.5 Conservation Options for the Ludlow Sub-Basin

Water conservation options that may be applicable to water users in the Ludlow Sub-basin are summarized below.

- Tiered Water Rate Structures
- Modification of Landscape Irrigation Practices
- Water Conservation in Water Supply Systems and Individual Homes
- Educational programs
- Water Re-Use
- Water Conservancy Boards To Facilitate Water Rights Transfers

11.7 DATA SYNTHESIS AND INTEGRATION

With moderate growth projected through 2016 in the lands adjacent to Shine Creek (64 percent in the Thorndyke/Shine/Paradise Bay region), and a tripling of population in the Port Ludlow area, consumptive use of groundwater is certain to rise. Current estimates of groundwater use in the Ludlow sub-basin range up to 683 af/y, which is only 3 percent of the estimated annual recharge in the sub-basin. Low summer flows have not been identified as limiting factors for fish production in either Shine Creek or Ludlow Creek. However, further groundwater development in the upper reaches of Shine Creek could influence base flow, because of high potential hydraulic continuity in the upper basin. Water quality has generally

exceeded state standards in the monitored tributaries of Mats Mats Bay, Ludlow Creek, and Shine Creek. Marine waters in Port Ludlow have also met standards for fecal coliform contamination.

11.8 DATA QUALITY, DATA GAPS AND LIMITATIONS

In addition to the general data gaps identified for the entire WRIA, the following specific data gaps have been identified for this sub-basin:

11.8.1 Water Quality

Surface water quality data gaps and limitations in this sub-basin are consistent with those discussed for the entire WRIA. Specific limitations include:

- There were no ambient water quality reports on Squamish Harbor, Paradise Bay watershed and Bywater Bay watershed.

11.8.2 Water Quantity

Water quantity data gaps have been identified for the entire WRIA and generally apply to the Ludlow sub-basin. The following additional definition of data gaps is based on consideration of currently existing data, and provides additional detail where possible:

- Variability in chloride concentrations in coastal wells may be associated with well completions in various water-bearing units, variability in groundwater levels, and local effects of pumping. Hydrogeologic characterization would be required to better define these relationships.

- Existing hydrogeologic characterization in the south Port Ludlow/Shine area (Robinson and Noble 1992) provides some definition of the inland hydrogeologic framework, but does not provide much detail regarding coastal conditions.

- Relatively high development densities occur in the Port Ludlow master planned resort. Densities are expected to increase over time. Better understanding of site runoff characteristics, soil permeabilities, and opportunities for stormwater infiltration may reduce potential hydrologic impacts associated with increased development.

- No long-term streamflow data is available for this sub-basin.

11.8.3 Habitat

- Inventory and delineation of critical winter rearing habitat in the lower reaches of the Shine Creek Basin.

- Scour and deposition in spawning areas used by coho salmon and other salmonids, to determine the consequences of high winter stream flow in Shine Creek.

- Quantify habitat quality in the lower reaches of Ludlow Creek, and identify critical areas higher in the drainage that require protection so that the productivity of lower basin habitat is restored.

11.8.4 Instream Flow

Instream flow data gaps for this sub-basin are the same as that identified for the entire WRIA. There is sufficient information to develop instream flow recommendations and to proceed with the setting of instream flows in most of the larger streams in the basin.

12. CHIMACUM SUB-BASIN

12.1 SUB-BASIN DESCRIPTION

The Chimacum sub-basin is located in a series of lowland hills that separate this sub-basin from Ludlow and Thorndyke sub-basins (Figure 12-1). The main water feature in this sub-basin is Chimacum Creek, which has two forks (east and west) that drain north to Port Townsend Bay. The upland geology consists of glacial deposits overlying shale, sandstone, and lava, while the lowland valleys are characterized by deep muck and peat soil. The drainage lies in the rain shadow of the Olympic Mountains, so less than 22 inches of precipitation falls annually on the lower valley, 35 inches in the headwaters. Average monthly flow typically declines to less than 5 cfs at the end of summer.

Land use is mostly forested in the upper and lower portions of the sub-basin, however the middle portions have been intensely developed with agricultural uses. Early settlers cleared and drained most of the valleys and channelized the creek before the 1900's (Williams et al.1975; Bahls and Rubin 1996). The riparian corridor between RM 3 and 9 has been mostly cleared and replaced with agricultural and residential uses (Lichatowich 1993a). Chimacum, Port Hadlock, and Irondale are rural communities located within this sub-basin.

12.1.1 Surface Water Features

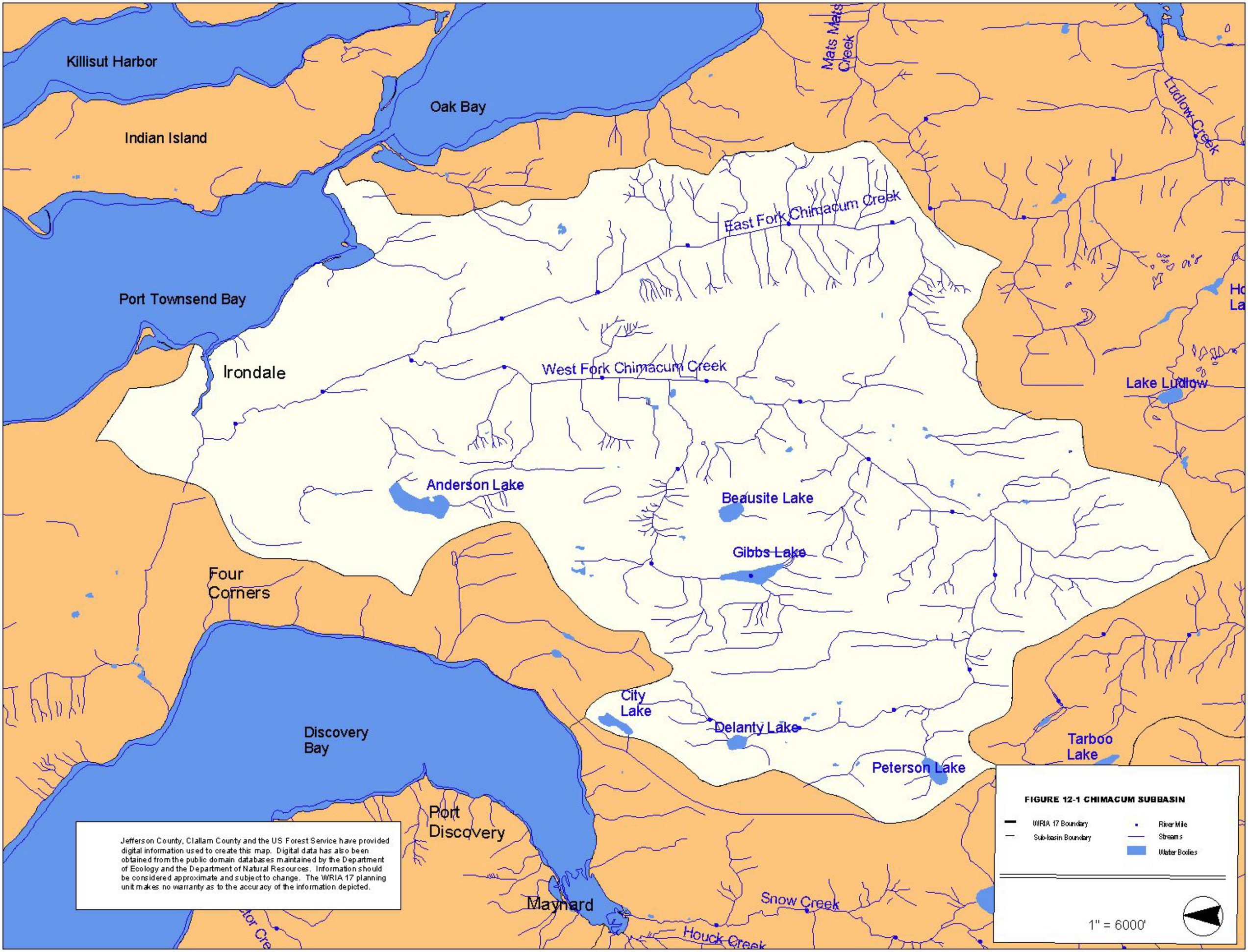
Chimacum Creek flows north out of two glacially carved lowland valleys in northeastern Jefferson County to the southern end of Port Townsend Bay, at Irondale. The East Fork and West Fork, together with small tributaries, comprise 29.5 miles of stream that converge into the mainstem at RM 2.7 (Bahls and Rubin 1996). The area of the watershed is approximately 37 square miles (PNTPC et al. 1999). The East and West forks represent one-third and two-thirds, respectively, of the total flow. The East Fork starts in the flat-bottomed Chimacum Valley, approximately four and one-half miles upstream from the confluence point at an elevation of 180 ft. The West Fork is longer, reaching into the uplands southeast of Discovery Bay. Flowing south from Delanty Lake at an elevation of 500 ft, the West Fork merges with a creek flowing out from Peterson Lake, also at approximately 500 ft, and first turns east then north towards the confluence point. The total length of the West Fork is approximately 10 miles. There are several lakes of significant size in the Chimacum sub-basin, the largest being Delanty Lake, Gibbs Lake, Beausite Lake and Anderson Lake. Only Gibbs Lake is connected to Chimacum Creek by a perennial stream

Both forks of Chimacum Creek have shallow gradients and the middle portions have been dredged and channeled to protect adjacent farmland from flooding (Williams et al. 1975). The remainder of the streams in this sub-basin are small (e.g., Naylors Creek and Putaansuu Creek) and generally have low or intermittent flows during summer months. Surface water features for the Chimacum sub-basin are summarized in Table 12-1.

Table 12-1 Fresh Water Features in the Chimacum Sub-basin

Main Water Feature	Tributary	Confluence	Ecology Class	DNR Class
Chimacum Creek			Class AA	2
	East Fork Chimacum Creek	RM 2.7	Class AA	2

Source: Williams et al. (1975)


Killisut Harbor
Oak Bay
Indian Island
Port Townsend Bay
Irondale
Four Corners
Discovery Bay
Port Discovery
Maynard
Mats Mats Creek
Ludlow Creek
East Fork Chimacum Creek
West Fork Chimacum Creek
Anderson Lake
Beausite Lake
Gibbs Lake
City Lake
Delanty Lake
Peterson Lake
Lake Ludlow
Tarboo Lake
Snow Creek
Houck Creek
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
FIGURE 12-1 CHIMACUM SUBBASIN
WRIA 17 Boundary
Sub-basin Boundary
River Mile
Streams
Water Bodies
1" = 6000'

12.1.2 Groundwater Features

Hydrogeologic characterization for the Chimacum sub-basin includes existing mapping of surficial geology, several generalized geologic cross-sections (PGG and EES 1994; Grimstad and Carson 1981), limited discussion of potential well yields (ibid), mapping of miscellaneous groundwater elevations (Grimstad and Carson 1981) and a local hydrogeologic study for the Port Townsend Sparling Well (CH2M Hill 1996). The sub-basin is characterized by extensive areas covered with glacial till, by broad valleys eroded through the till into underlying principal aquifer materials, by the presence of peat or bog materials over significant areas in the bottoms of these valleys, and by spotty outcrops of bedrock of both sedimentary and volcanic origin. Generalized surficial geology for the Chimacum sub-basin can be seen on Exhibit 17. Principal aquifer materials are composed of pre-Vashon stratified glacial drift, interglacial deposits, and Vashon advance outwash. Exposures of principal aquifer materials are noted along the incised valleys. Bedrock exposures are noted along the western edge of the sub-basin near Anderson Lake, Gibbs Lake, southeast of Peterson Lake, and along the east fork of Chimacum Creek. Although the known distribution of wells penetrating bedrock is not extensive, most geologic interpretations surmise that bedrock is relatively shallow, and the thickest sequences of principal aquifer materials occur beneath upland areas. A number of high-yielding wells have been reported in the Chimacum valley(s) (Grimstad and Carson 1981); however well yields from unconsolidated sediments can be highly variable. Bedrock tends to yield lesser quantities of groundwater.

12.1.3 Land Use

Between RM 1.3 and RM 3.0, 40 percent of the adjacent land is in agricultural use, 17 percent in rural residential use, and 16 percent urban or commercial use (Ames et al. 2000). Below RM 1.3 the mainstem flows through a confined, forested ravine, then passes through a relatively intact estuarine lagoon and salt marsh.

The upper watershed of Chimacum Creek is comprised of agricultural, forestry, and rural residential land use. Overall, there are 3,032 acres zoned for agriculture in the Chimacum Creek watershed, representing about 14 percent of the total watershed area. The lower reaches, Chimacum Creek flow through more residential and commercial land uses. Rural residential zoning is found in approximately 9,141 acres (40 percent of the sub-basin). A total of 152 acres of land is zoned commercial in the Chimacum Creek watershed (0.7 percent of the total). The predominant residential zoning in this watershed (4,112 acres) is one residence per 20 acres.

The lower reaches of the Chimacum Creek watershed are influenced by residential and commercial land use in the Tri-Area (Irondale, Port Hadlock, and Chimacum). The most dense residential and commercial development of the riparian zone has occurred between RM 1.3 and RM 4.0. Land use in this sub-basin is shown in Table 12-2.

Table 12-2. Chimacum Sub-basin Land Use

Description	No. of Parcels	Acres	% of Total
Rural Residential (1:5)	3,030	1,828	8.1%
Rural Residential (1:10)	546	2,952	13.0%
Rural Residential (1:20)	422	4,361	19.3%
Parks, Preserves, Recreation	41	719	3.2%
Rural Forest	47	1,339	5.9%

Table 12-2. Chimacum Sub-basin Land Use (continued)

Description	No. of Parcels	Acres	% of Total
Commercial Forest	152	7,288	32.2%
Inholding Forest	6	43	0.2%
Airport and Waste Management Facilities	2	7	0.0%
Commercial Agriculture	146	3,032	13.4%
Rural Village Centers (Hadlock, Chimacum, Irondale)	100	76	0.3%
Resource Based Industrial Zone (Center)	1	4	0.0%
Tidelands	51	188	0.8%
Roads and Right of Way	293	814	3.6%
Totals	**4,838**	**22,651**	**100.0%**

Source: Jefferson County (2000)

12.2 WATER QUALITY

12.2.1 Surface Water Quality

Freshwater quality data sources for this sub-basin are summarized in Table 12-3.

Table 12-3 Surface Water Quality Data Available for the Chimacum Sub-basin

Areas	Parameters							Years Sampled	No. of Sample Locations	Reference
	Temp	DO	pH	FC	Turb	Cond	Nut			
Chimacum Creek	X							1992-1995	4	Bahls unpublished as seen in Bahls and Rubin (1996)
Chimacum Creek	X							1992	1	Bahls (1993)
Chimacum Creek	X	X						1995	22	Bahls and Rubin (1996)
Chimacum Creek	X	X	X	X				1988, 89, 95-2000	35	JCCD (2000)
East Fork Chimacum Creek	X	X	X	X				1988,89, 96-2000	11	JCCD (2000)
Naylors Creek	X	p	p	p	p	p	p	1998	2	Gately (1999)
Putaansuu Creek	X	X	p	p	p	p	p	1998	2	Gately (1999)
Chimacum Creek	X	X	p	X	p	p	E	1998	7	Gately (1999)
East Fork Chimacum Creek	X	X	p	X	p	p	p	1998	5	Gately (1999)

X = water quality was exceeded for at least one sample

p = no water quality data exceeded applicable standards.

E = Excessive phosphorus and nitrate-nitrogen (Gately 1999).

Parameters were summarized by Gately (1999) on four streams monitored in 1998. FC exceeded state water quality standards in Chimacum Creek at RM 7.8 down stream to RM 3.4, and on the East Fork at RM 4.8 downstream to RM 0.2. Nutrients (TP and NO3-N) generally increased from upstream to downstream. Most of the loading appears to be coming from the mainstem Chimacum Creek at RM 3.4 as compared to the East Fork Chimacum. Temperature exceeded state water quality standards in mainstem Chimacum from RM 9.0 to RM 0.1, the East Fork Chimacum Creek from RM 3.3 to RM 1.3, at Naylor Creek RM 0.2, and in Putaansuu Creek at the mouth (Table 12-3). Average DO concentrations exceeded state water quality standards in the mainstem Chimacum Creek at RM 3.4, 6.7, and 7.8, East Fork Chimacum Creek at RM 4.8 downstream to RM 0.2, and in Putaansuu Creek at the mouth.

Data was compiled by the JCCD from Chimacum Creek and East Fork Chimacum Creek from 1988 to present. Data from the main sampling stations are summarized in Table 12-4. Parameters exceeded the state water quality standards for Class AA streams at seven stations out of 35 on the Chimacum Mainstem, and temperature, FC, and DO were exceeded at four stations out of 11 in the East Fork Chimacum Creek.

Table 12-4. Water Quality Data for Chimacum Sub-basin (JCCD 2000)

Area	Site	Date sampled	Temp (C)	Cond (µmhos/ cm)	pH	DO (mg/L)	FC GMV (FC/ 100 mL)	Turb (NTU)	NO3-N	TP
Class AA Standard			**<16.0**	**NA**	**6.5 - 8.5**	**>9.5**	**GMV <50 and <10% >100**			
Chimacum Creek	CH/0.0	11/7/95, 1/1/97	6 - 6.6	108 - 231	6.6 - 7.9	9.8 - 11.1	NA	120	NA	NA
	CH/0.07	10/7/99 - 2/8/00	3.6 - 11.2	NA	NA	**8.1** 10.8	NA	NA	NA	NA
	CH/0.27	10/7/99 - 2/8/00	3.8 - 11.2	NA	NA	**8.1** 10.5	NA	NA	NA	NA
	CH/0.34	10/7/99 - 2/9/00	3.8 - 11.3	NA	NA	**8.2** 10.7	NA	NA	NA	NA
	CH/1.1	2/9/88 - 2/16/00	4.0 - 15.9	107 - 280	**6.1** - 7.8	**8.4** - 15.6	**55**	2.3 - 56	0.3 - 2.5	0.022 - 0.065
	CH/2.3	2/26/96 - 2/16/00	5.0 - 15.5	190 - 233	6.7 - 7.5	**9.0** - 11.1	NA	4.0 - 13	0.5 - 2.15	NA
	CH/3.4	2/9/88 - 2/16/00	3.9 - **22.7**	98 - 234	**6.2** - 7.5	**4.4** - 14.1	**159**	1.1 - 56	0.2 - 1.6	0.03 - 0.1
	CH/3.9	2-26/96 - 9/6/99	2.8 - **21.0**	161 - 213	6.6 - 7.1	**3.2** - 12.2	NA	1.1 - 15	NA	NA
	CH/5.3	2/9/88 - 2/16/00	3.0 - **20.2**	98 - 281	6.9 - **8.8**	**2.3** - 13.8	**54**	1.3 - 33	0.25 - 1.4	0.016 - 0.09
	CH/6.7	2/9/88 - 2/16/00	4.0 - 14.2	101 - 219	6.9 - 7.4	**5.8** - 11.7	**95**	1.3 - 7.8	0.2 - 1.4	0.017 - 0.072
	CH/7.8	6/9/98 - 2/16/00	4.5 - 14.5	102 - 213	7.0 - 7.6	**8.6** - 11.9	42	2.2 - 8.7	0.3 - 1.4	0.01 - 0.05
	CH/8.8	2/9/88 - 2/16/00	4.4 - 17.2	47 - 182	**6.2** - 8.0	**8.7** - 14.2	**61**	0.8 - 675	0.2 - 1.4	0.0025 - 0.039
	CH/9.3	2/9/88 - 2/16/00	2.1 - 14.9	48 - 195	**6.3** - 8.0	**4.7** - 14.4	13	0.4 - 1025	0.31 - 1.98	0.0025 - 0.037
East Fork Chimacum Creek	ECH/0.2	2/9/88 - 2/16/00	4.0 - 15.0	153 - 318	6.6 - 7.5	**7.9** - 13.6	**57**	3.4 - 16.0	0.37 - 3.55	0.002 - 0.044
	ECH/0.7	6/21/99 - 9/6/99	10.9 - 14.5	NA	NA	**4.8 - 7.0**	NA	3.7 - 11.8	NA	NA
	ECH/1.0	2/9/88 - 2/16/00	5.0 - **17.0**	181 - 278	6.9 - 7.2	**4.0** - 11.0	**85**	2.6 - 63.5	0.34 - 3.5	0.002 - 0.065
East Fork Chimacum Creek (con't)	ECH/1.3	7/8/98 - 8/30/99	4.8 - 16.0	NA	NA	**3.4** - 11.9	NA	2.3 - 1806	NA	NA
	ECH/1.8	7/8/98 - 8/30/99	4.5 - **17**	NA	NA	**2.8** - 13	NA	1.6 - 136	NA	NA
	ECH/2.2	6/21/99 - 9/6/99	10.5 - 13.5	NA	NA	**8.1 - 9.3**	NA	4.0 - 9.7	NA	NA

Table 12-4. Water Quality Data for Chimacum Sub-Basin (JCCD 2000) (continued)

Area	Site	Date sampled	Temp (C)	Cond (µmhos/ cm)	pH	DO (mg/L)	FC GMV (FC/ 100 mL)	Turb (NTU)	NO3-N	TP
Class AA Standard			**<16.0**	**NA**	**6.5 - 8.5**	**>9.5**	**GMV <50 and <10% >100**			
	ECH/2.8	6/21/99 - 9/6/99	10.8 - 13.5	NA	NA	**7.8 - 9.1**	NA	4.2 - 10.3	NA	NA
	ECH/3.3	2/9/88 - 2/16/00	3.2 - 15.5	122 - 253	6.6 - 7.6	**4.9** - 11.3	**67**	2.7 - 25	0.38 - 3.1	0.028 - 0.074
	ECH/4.8	5/2/88 - 2/16/00	3.2 - 16.0	56.3 - 205	**5.7** - 7.6	**6.0** - 11.7	**61**	1.5 - 82	0.39 - 2.04	0.019 - 0.084
	ECH/5.3	4/7/98 - 2/16/00	5.9 - 11.9	85 - 170	7.4 - 7.9	**9.4** - 11.8	5	1.6 - 9.3	0.39 - 1.6	0.016 - 0.071

NA = Data not available.

BOLD indicates exceeds state water quality standards.

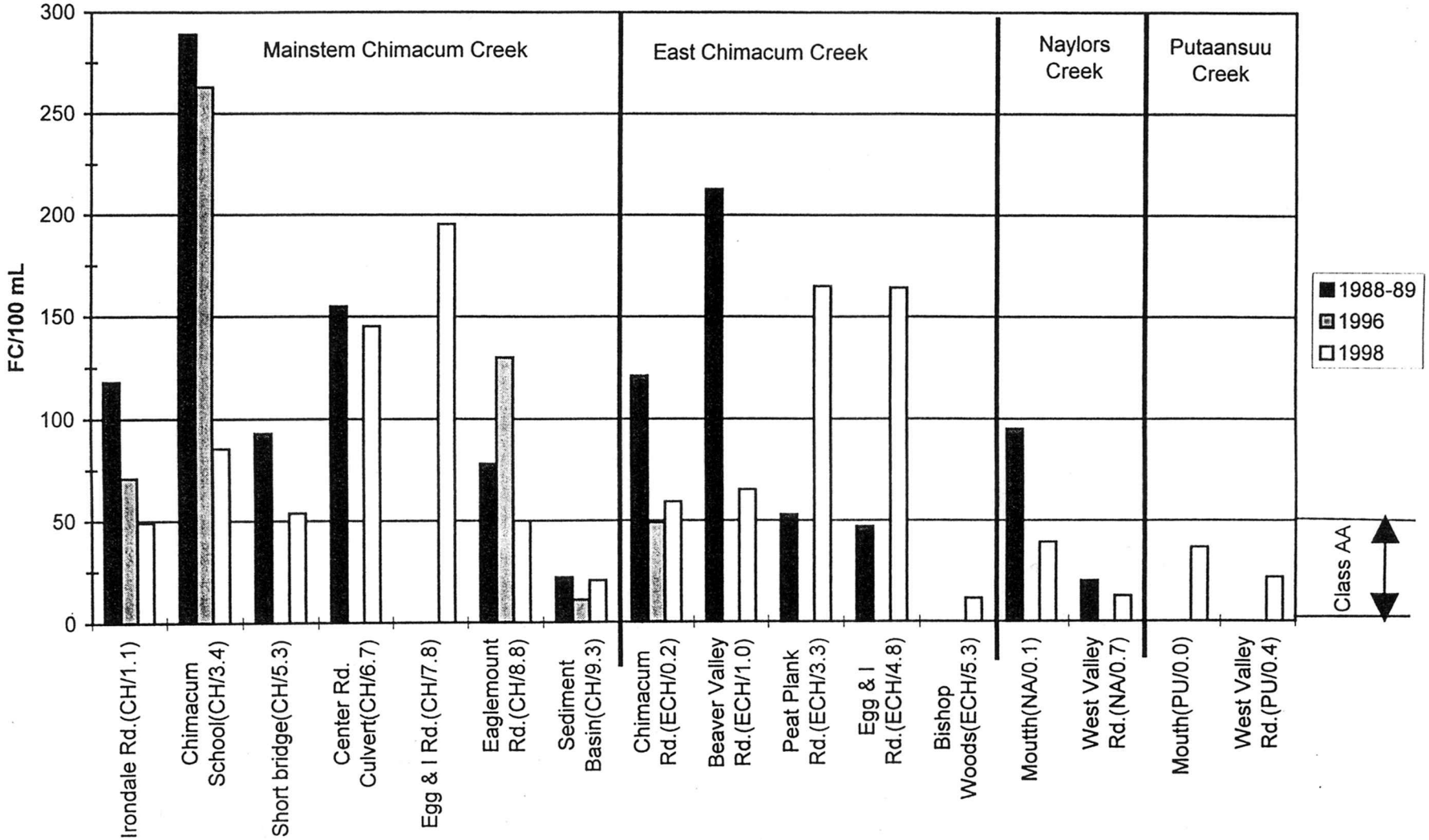
Water quality trends (JCCD 2000) for Chimacum Creek mainstem are shown in Figures 12-2 through 12-7. FC, turbidity, temperature, have tended to remain about the same from upstream to the mouth. Conductivity, NO3-N, and TP increase from upstream to downstream, and DO decreases further downstream with an increase at the mouth to above state standards. PH, not included in the figures, tended to remain the same from upstream to downstream.

Water quality trends for East Chimacum Creek are shown in Figures 12-8 through 12-10. In general, FC, and NO3-N tend to remain at the same levels from upstream to downstream. Temperature, turbidity, and conductivity increase from upstream to downstream, and DO and TP decrease from upstream to downstream. PH, not included in the figures, tended to remain the same form upstream to downstream.

A study by Bahls (1993) measured instream temperatures every 10 days between August 4 and October 2, 1992. A high temperature of 72 °F/22 °C was recorded, which exceeds state water quality standards for Class AA streams.

Another study conducted by Bahls and Rubin (1996) measured continuous temperature and DO conditions at 22 sites in Chimacum Creek between July 22 and September 11, 1995. Results indicate a trend of increasing temperatures and decreasing DO concentrations from the headwaters to mainstem monitoring stations; maximum temperatures exceeded 20 °C at sites 14 and 12, and minimum DO concentrations were 0.8 mg/L at sites 10 and 11, which both exceed state water quality standards (Bahls and Rubin 1996). Numerous other monitoring sites also exceeded state water quality standards for temperature and DO.

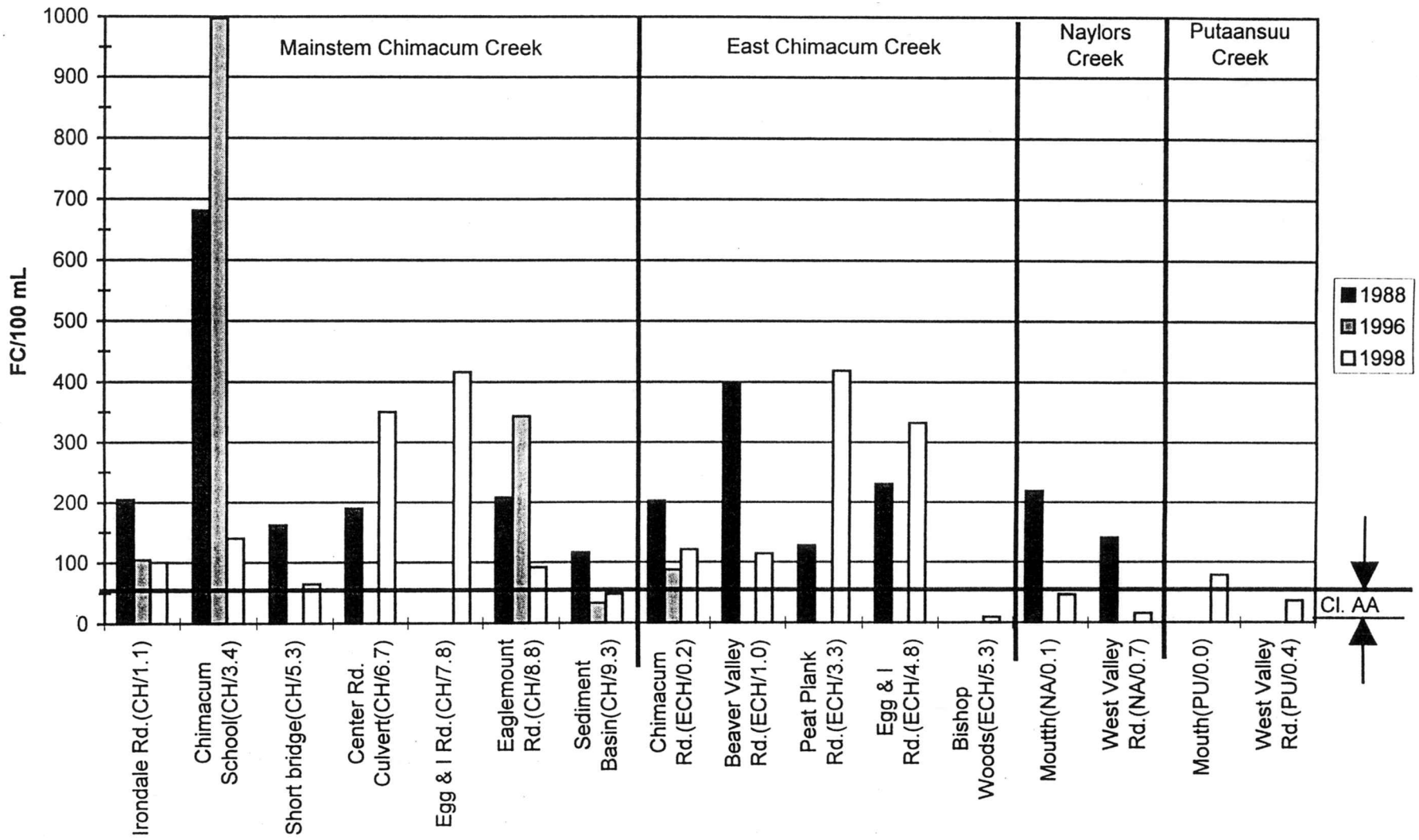
Stream flow, turbidity and temperature were recorded by the City of Port Townsend between December 17, 1997 and September 17, 1999 (City of Port Townsend 1999). Temperature and stream flow data is presented in Figure 12-11. Temperature exceeded state standards during summer periods.



NOTE: Fecal coliform geometric mean values (GMVs) at stations monitored monthly during 1988-89, and 1998 in the Chimacum Creek Watershed.

Source: Gately, 1999.

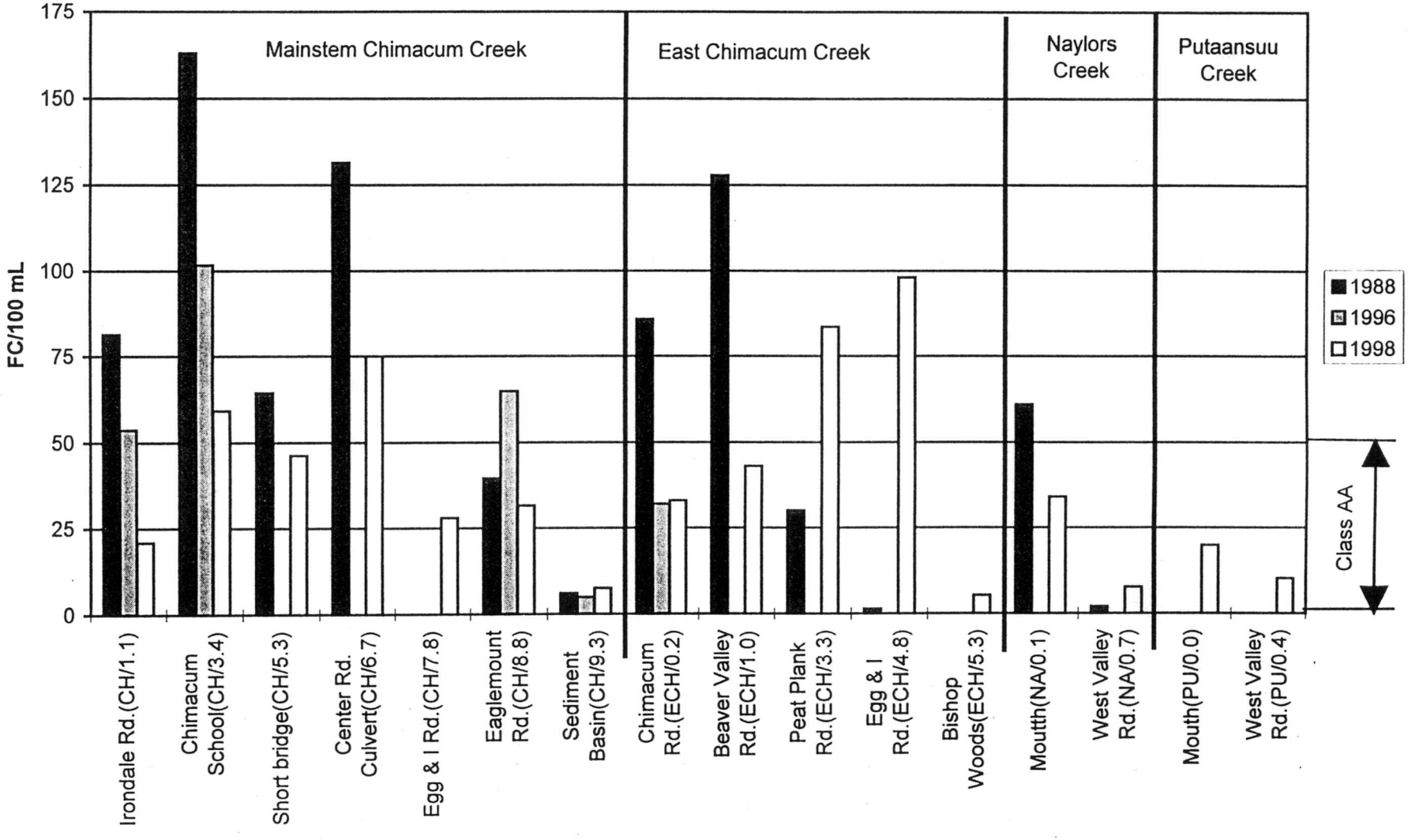
Figure 12-2
Fecal Coliform Concentration
Chimacum Creek Main Stem,
All Months



NOTE: Fecal coliform geometric mean values (GMVs) at stations monitored monthly during the dry season (June - October) in 1988-89, and 1998 in the Chimacum Creek Watershed.

Source: Gately, 1999.

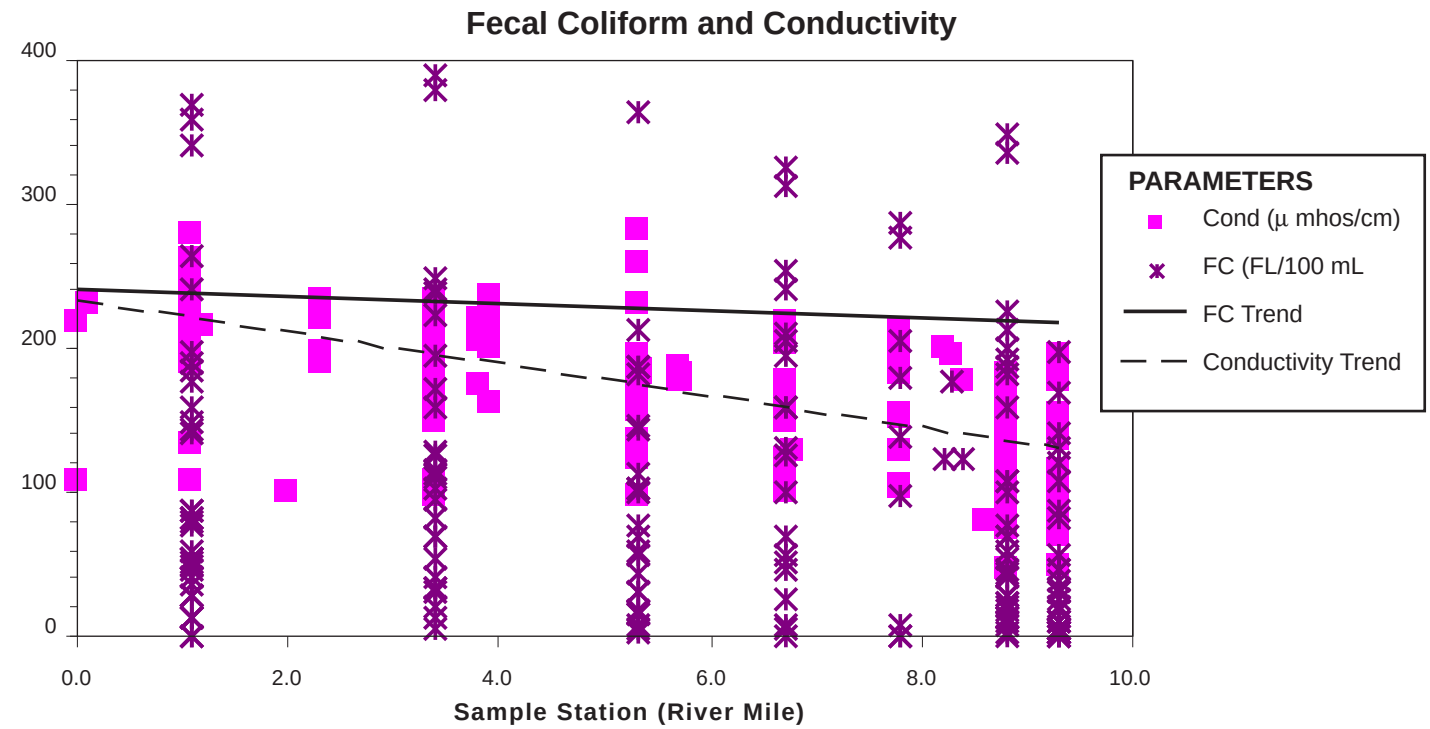
Figure 12-3
Fecal Coliform Concentration
Chimacum Creek Main Stem,
Dry Months (June – October)



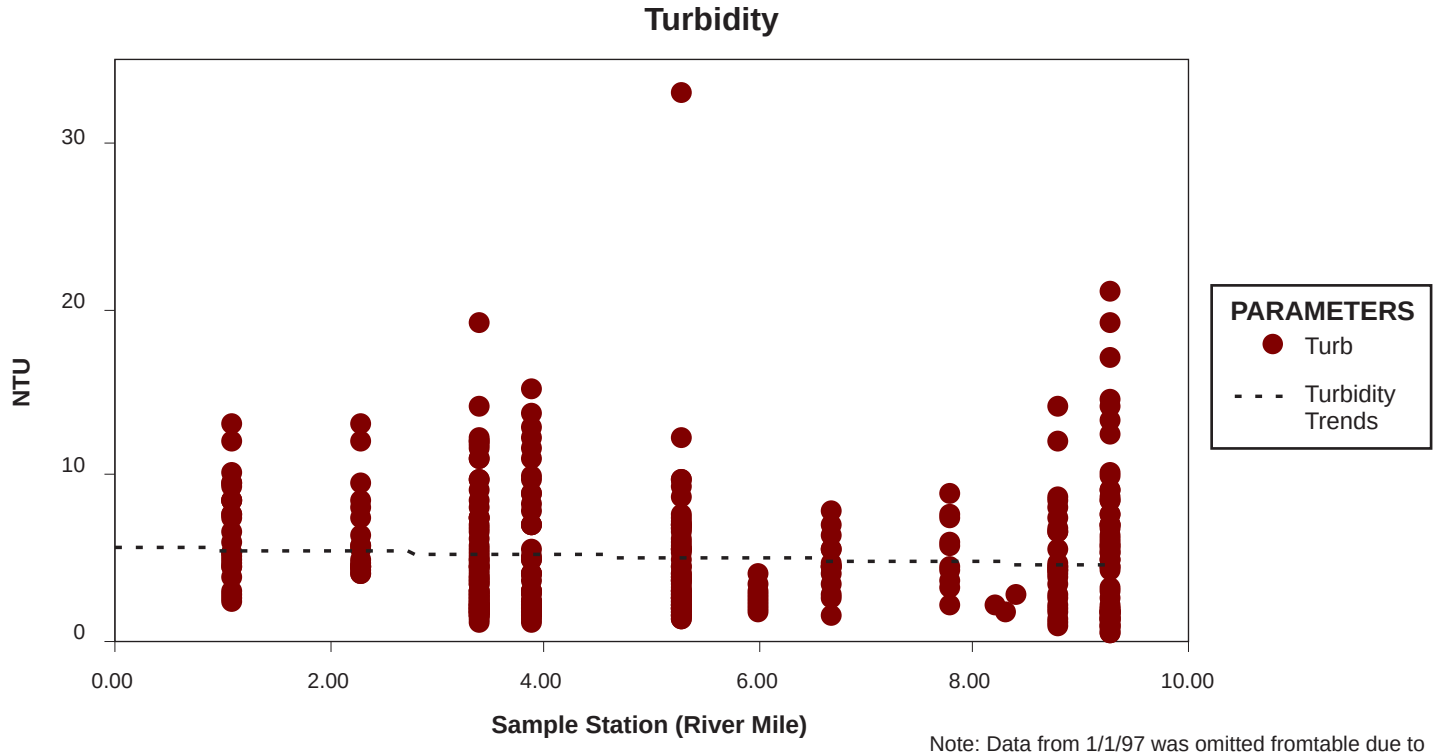
NOTE: Fecal coliform geometric mean values (GMVs) at stations monitored monthly during the wet season (November - May) in 1988-89, and 1998 in the Chimacum Creek Watershed.

Source: Gately, 1999.

Figure 12-4
Fecal Coliform Concentration
Chimacum Creek Main Stem,
Wet Months (November – May)



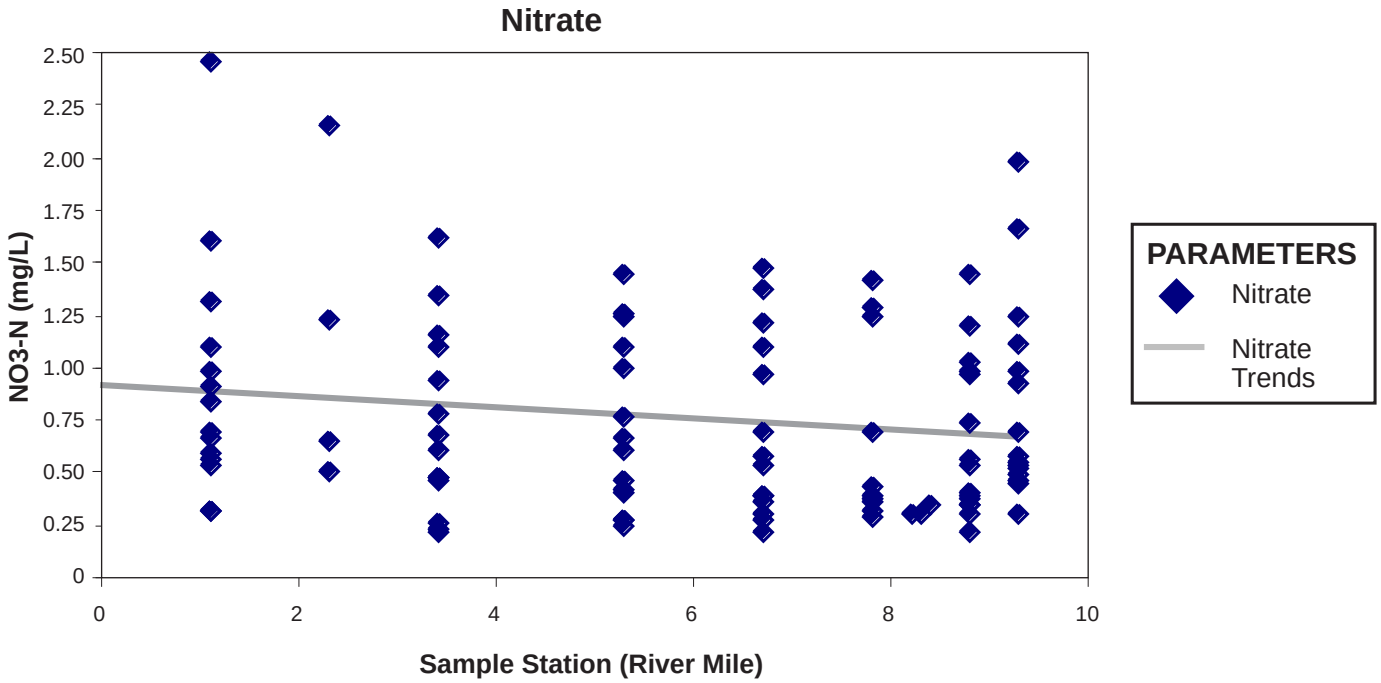
Note: FC data is off scale for stations 3.4 (7 points, 670 – 3540), 6.7 (2 points, 1400, 2640), 7.8 (1 point, 5500), and 8.8 (2 points, 2233, 3300).

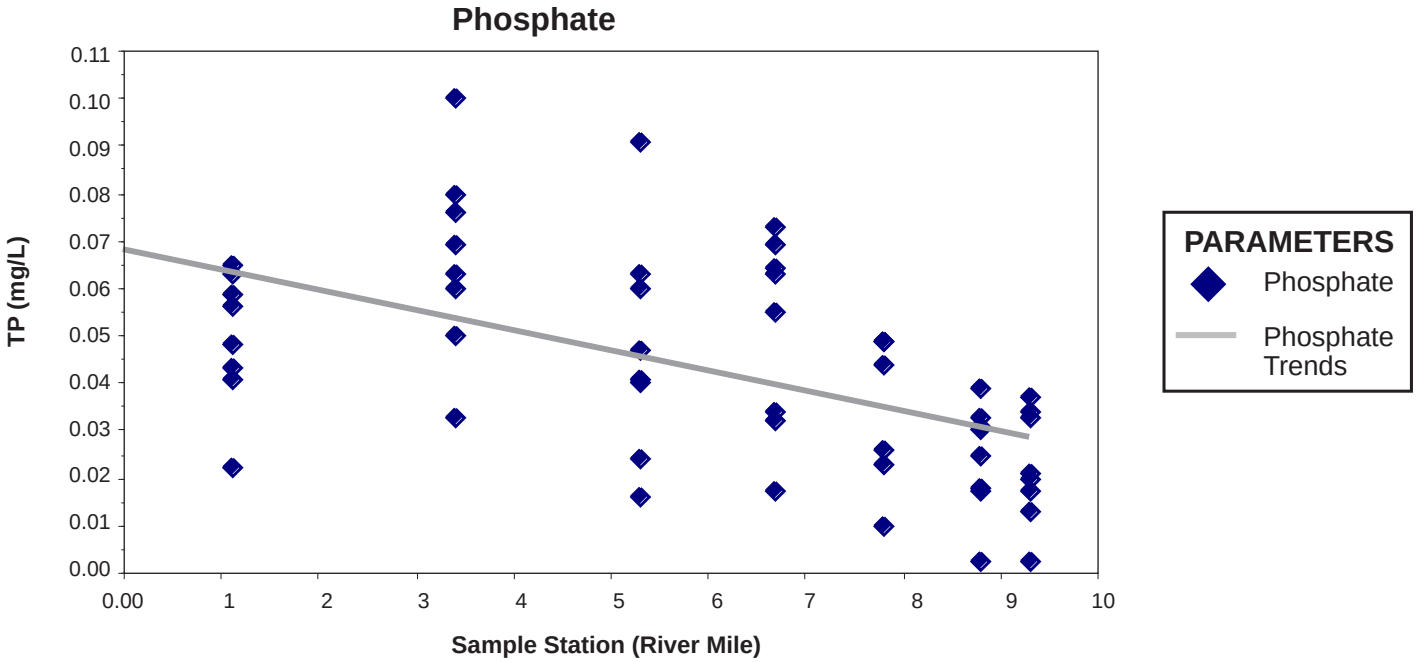


Note: Data from 1/1/97 was omitted fromtable due to extremely high results at 6 sites, indicating a storm event (56 – 1025 NTU).

Source: JCCD

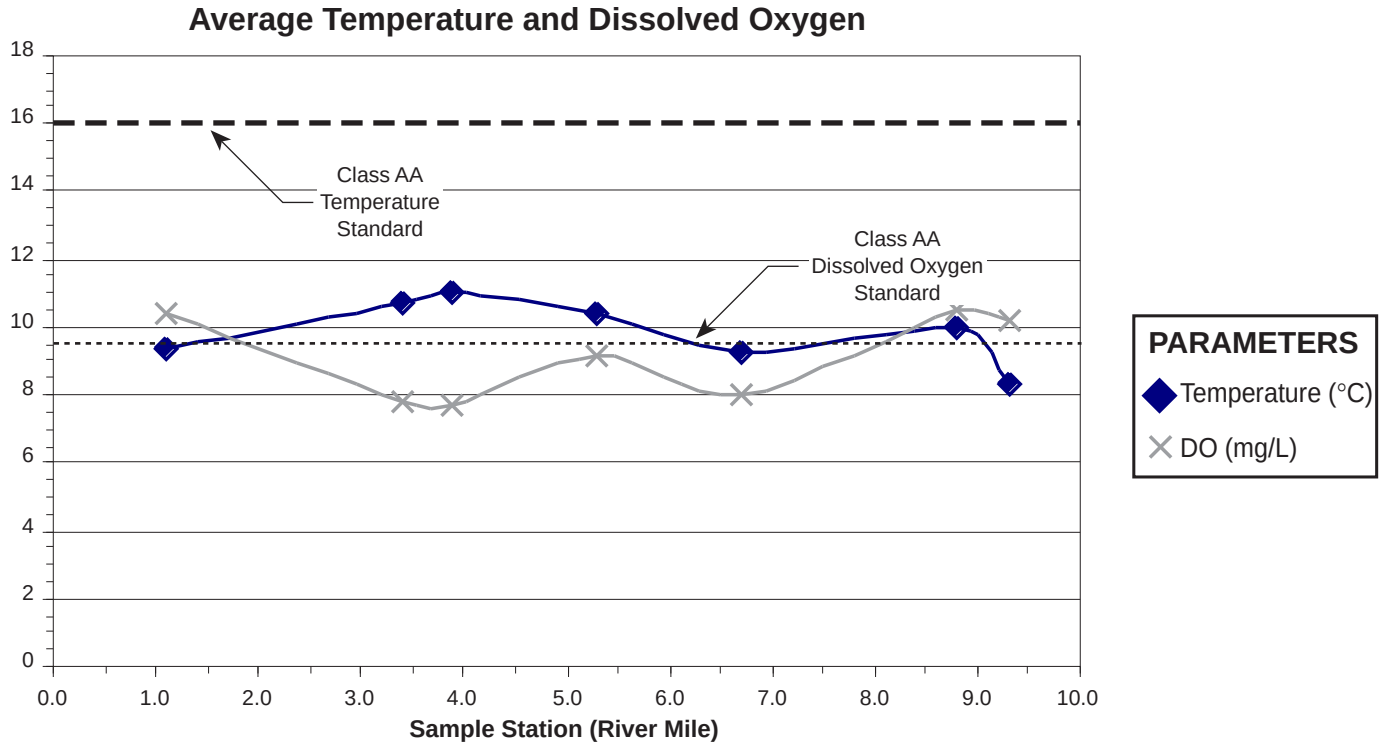
Figure 12-5
Fecal Coliform Conductivity, and Turbidity Trends in Main Stem Chimacum Creek, February 1988 – February 2000





Source: JCCD

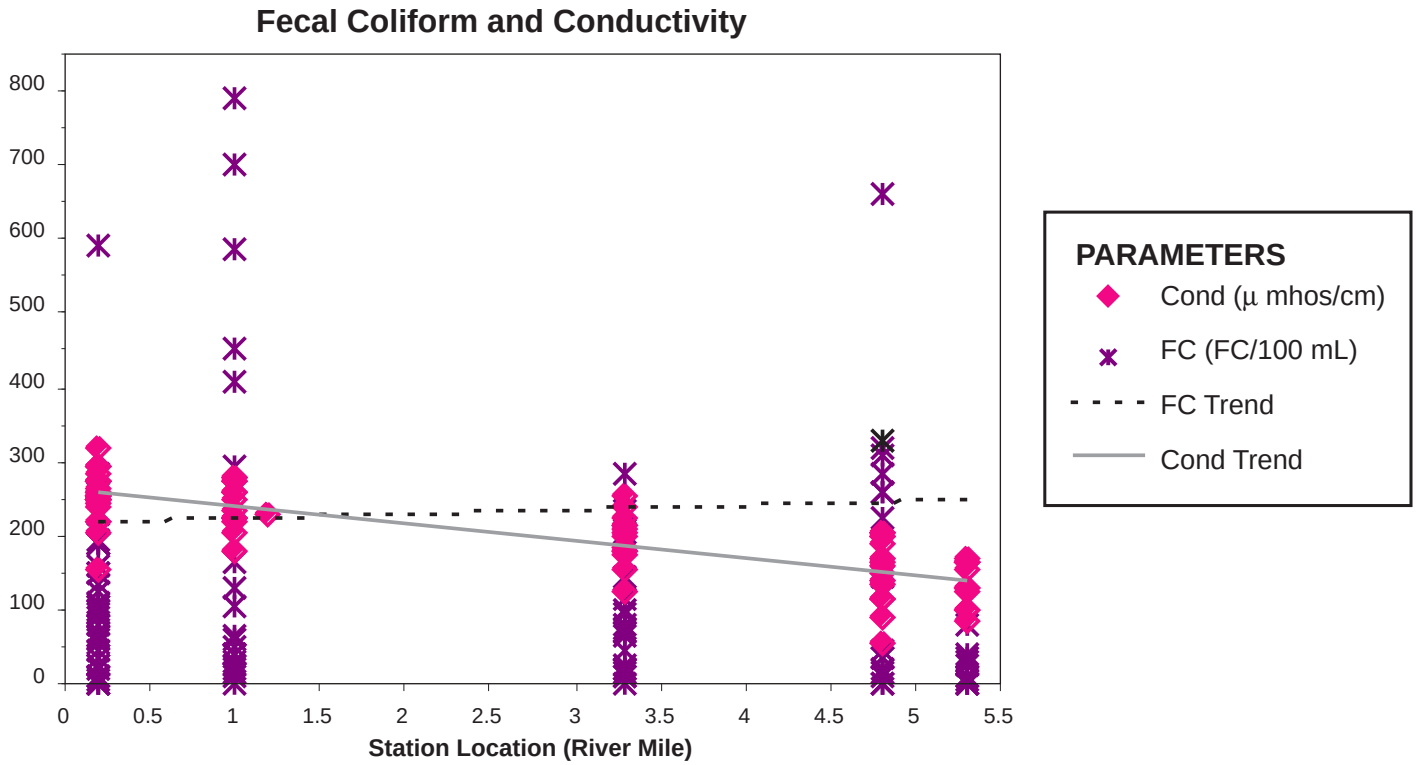
Figure 12-6
Nitrate and Phosphate Trends in Main Stem Chimacum Creek, February 1988 – February 2000



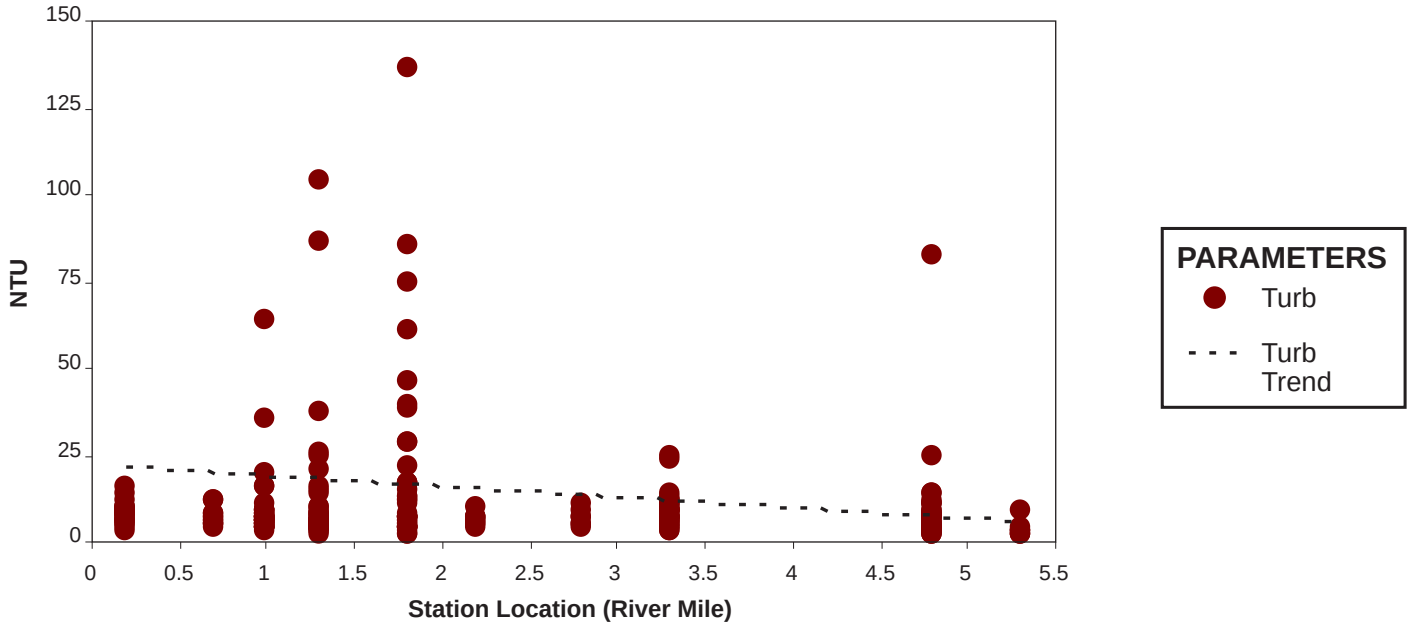
Note: Data shown represent average of available data from the 1996-2000 period. Number of samples range from 12 at RM 6.7, to 77 at RM 3.4.

Source: JCCD

Figure 12-7
Average Temperature and Dissolved Oxygen in Mainstem Chimacum Creek, January 1996 – February 2000



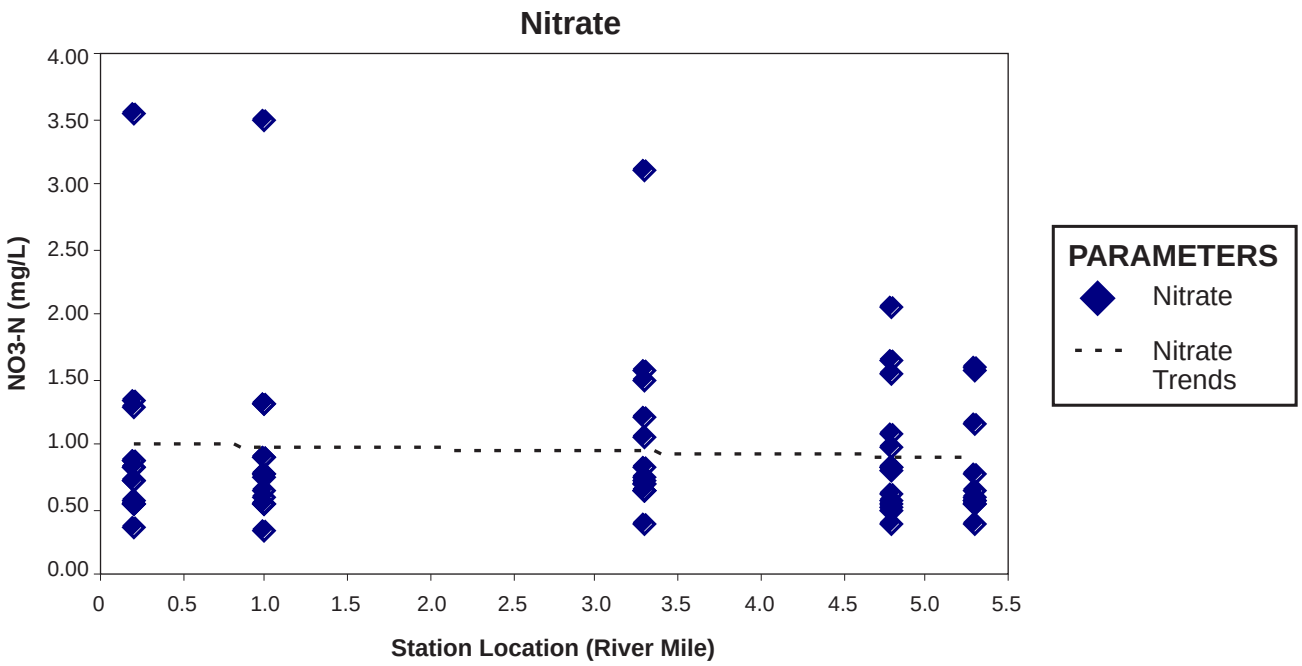
Note: FC results off scale at 4 locations:
0.2 (1760), 1.0 (1100, 1690), 3.3 (3 points, 1320 – 2860), and 4.8 (2420).

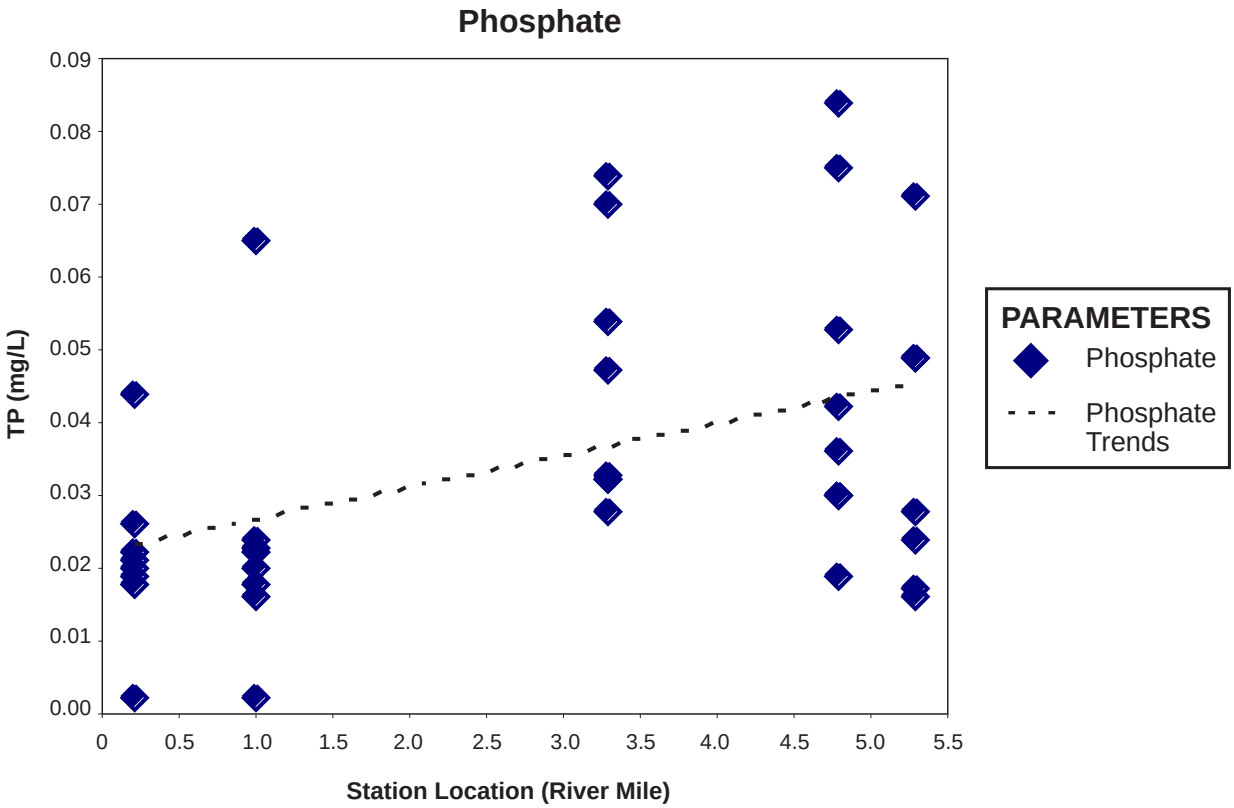


Note: Turbidity off scale at station 1.3 (1806 NTU) on 3-9-99.

Source: JCCD

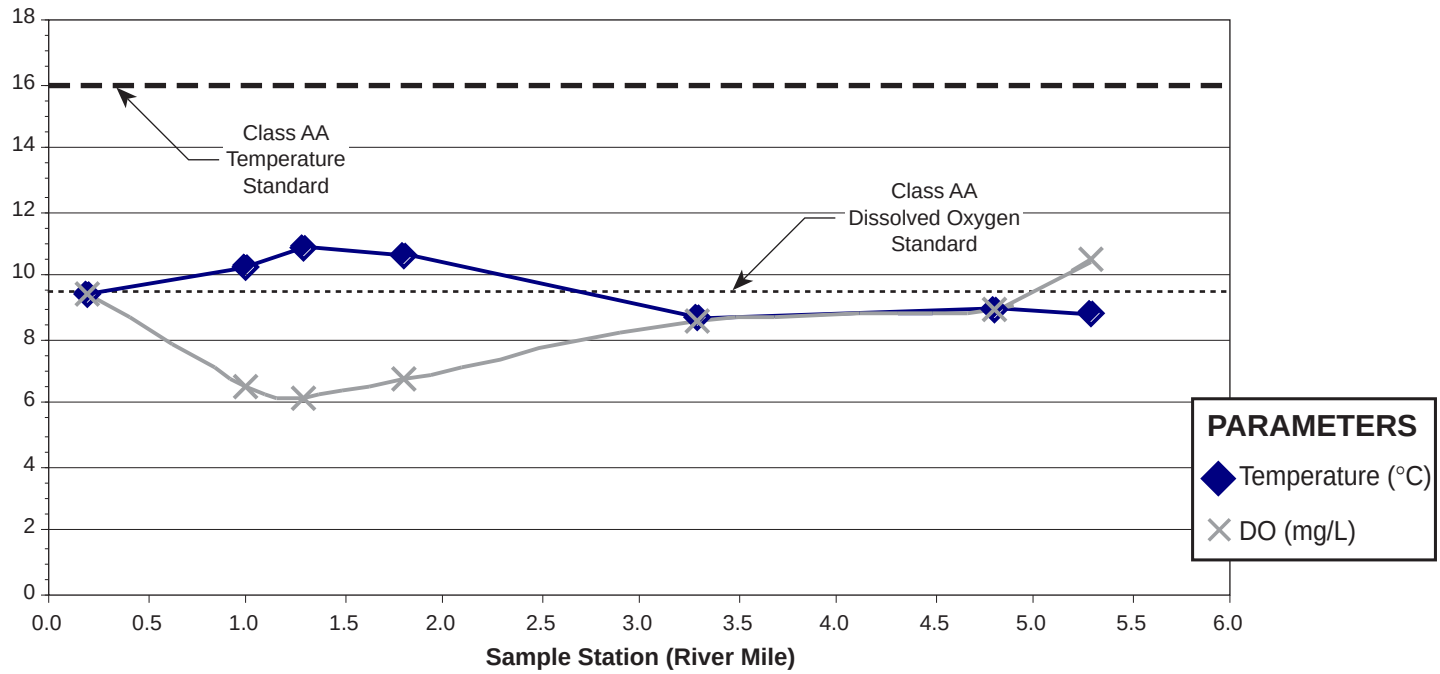
Figure 12-8
Fecal Coliform Conductivity and Turbidity Trends in East Fork Chimacum Creek, February 1988 – February 2000





Source: JCCD

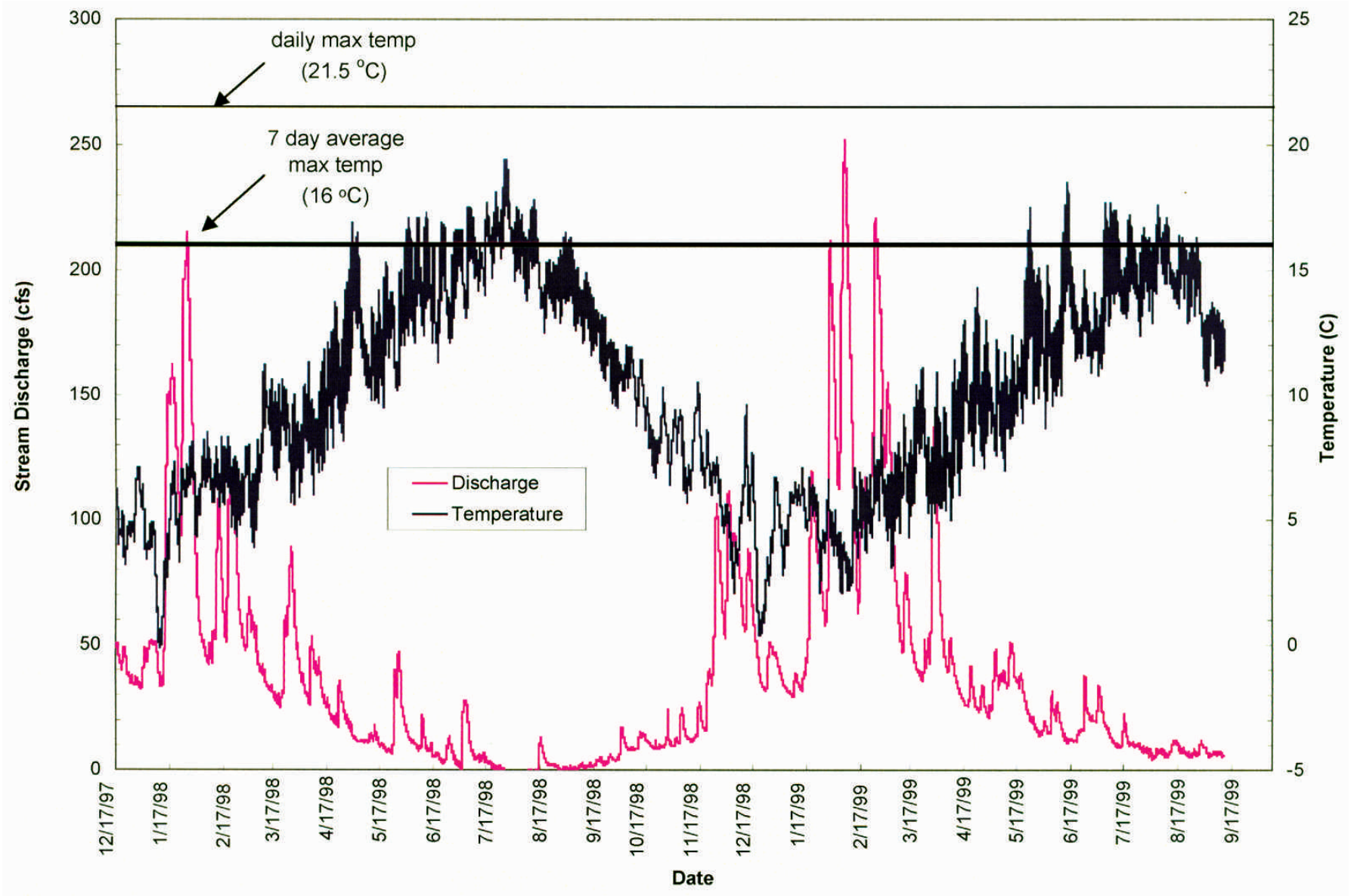
Figure 12-9
Nitrate and Phosphate Trends in East Fork Chimacum Creek, February 1988 – February 2000



Note: Data shown represent average of available data from the 1996-2000 period.
Number of samples range from 11 at RM 5.3, to 61 at RM 1.0.

Source: JCCD

Figure 12-10
Average Temperature and Dissolved Oxygen in East Fork Chimacum Creek, January 1996 – February 2000



Source: City of Port Townsend

Figure 12-11
Chimacum Creek Station CH/2.3 Flow Temperature Data
December 17, 1997 – September 17, 1999

Gately (1999) conducted FC monitoring at seven locations on the mainstem of Chimacum Creek, five locations on the east fork, two locations on Naylors Creek, and two locations on Putaansuu Creek. The primary finding was that several sites exceed water quality criteria. However, the percentage of sites with water quality exceedances decreased from 75 percent in 1988-89, to 60 percent in 1996, and to 50 percent in 1998. However, these results also indicate that total FC loading (in billions of FC/day) at the most downstream station has increased from 41 in 1988-89, to 49 in 1996, to 55 billion in 1998 (Gately 1999). The increase was primarily during wet weather conditions, and Gately speculated that the trend might have actually shown a decrease if rain and stream flow had been consistent during the study period. In support of this theory he mentioned that 8.7 miles of fencing had been installed on Chimacum Creek since 1988. Data collected by Gately are shown in Figures 12-2 through 12-4.

12.2.2 Marine Water Quality

Water quality in Port Townsend Bay is generally considered good. A DOH ambient monitoring report for FC in Port Townsend Bay resulted in approval of the area for shellfish harvesting. Table 12-5 summarizes the results of this investigation (DOH 1999a).

Table 12-5. Fecal Coliform Monitoring Results in Port Townsend Bay for 1993-1998

Station	No. of Samples	Range	Geometric Mean	Meets Standard
5	30	1.7-130.0	3.9	Yes
6	30	1.7-7.8	1.9	Yes
7	31	1.7-7.8	1.8	Yes
17	30	1.7-17.0	2.2	Yes
18	31	1.7-1600.0	4.4	Yes
19	31	1.7-31.0	3.0	Yes

Source: DOH (1999a)

12.2.3 Inventory of Potential Surface Water Contaminant Sources

12.2.3.1 *Point Sources*

Point sources, each with an individual NPDES permit, are summarized below from Ecology (1999a):

- Courtesy Ford Port Townsend
- WA DOT Portage Canal Bridge 1165
- Glenns Auto Shop Inc
- Cotton Redi Mix Shold Excavating
- Jefferson County Shop
- Evergreen Fiber Inc.
- Community Shell
- Jefferson County Health Dept
- Blaine City Marine DR Sewage

It is noted that NPDES point source locations have been provided by Ecology and in some cases may depict facility names and locations that may not be entirely representative of existing conditions. The Ecology database does also not distinguish between stormwater and/or wastewater permits. No specific monitoring data or compliance problems were available for these specific point sources.

12.2.3.2 *Non-Point Sources*

Agriculture such as livestock and hay production in the Chimacum Creek Valley has been identified as one of the main sources of pollutants in this sub-basin. Extensive agricultural BMPs have been implemented by area landowners over the last 10 to 15 years including over 55,000 lineal feet of stream fencing (JCCD 2000). Residential development in the towns of Chimacum, Port Hadlock and Irondale are also potential non-point sources.

12.2.3.3 *Summary of Trends and Compliance Problems*

Ecology listed Chimacum Creek on the 303(d) list for exceeding temperature and FC criteria. Data submitted by Bahls (1995-1997) indicated that temperature criteria were exceeded at RM 3.5 and 8.8 on the main stem of Chimacum Creek, and at RM 1.0 on the East Fork of Chimacum Creek in 1992 and 1994.

Ecology has placed Port Townsend Bay on the 1996 303(d) list for exceeding PCB criteria (Ecology 1998a). However, the Bay was removed from the 1998 list when sediment sampling conducted near the outfall of the Port Townsend paper mill indicated that PCB concentrations were below established criteria.

12.2.4 Groundwater Quality

Chloride concentrations in the Chimacum Sub-Basin are mapped on Exhibit 4. The sub-basin contains little coastal exposure and there is no evidence of elevated chloride concentrations. Exhibit 5 presents a map of nitrate concentrations in the sub-basin. A cluster of elevated nitrate concentrations is noted in the upper reaches of the watershed south of “Egg and I” Road. Variable nitrate concentrations are noted in this area, ranging from background levels to values between 2 and 5 mg/l. This geographic variability suggests that incidences of elevated nitrate are most likely localized to the areas of detection.

Groundwater contamination from a leaking underground storage tank is reported at the Chimacum School District; however reviewed references provide no evidence that this leak has compromised drinking water for other groundwater users.

12.3 WATER QUANTITY

12.3.1 Groundwater Quantity

Groundwater recharge estimated for the Chimacum sub-basin is approximately 18,700 af/yr, and averages 9.5 in/yr over the entire area. Exhibit 6 shows that recharge varies from 5 to 15 in/yr over glacial till, to 10-20 in/yr in areas without till cover. Recharge through till can be less than 12 in/yr in the northern areas of the sub-basin, where precipitation minus plant evapotranspiration does not exceed the transmitting capacity of the till. Approximately 62 percent of the sub-basin is covered by shallow till. Precipitation averages 27 in/yr over the sub-basin, and is unlikely to cause rejected recharge (i.e. runoff) in most areas.

12.3.2 Surface Water Quantity

Stream gage records were available for two sites on Chimacum Creek. The first gage was operated by the USGS from 1952 to 1957. The gage location is shown in Exhibit 2 and is located in the SW one-quarter of section 26, T29W, R1W. The drainage area at that point is 13.8 square miles. The USGS gage record

names the gage "Chimacum Creek near Chimacum". It appears the location of the gage is on what is now named the West Fork Chimacum Creek. An analysis of the USGS stream gage record was performed to determine how streamflow has varied historically throughout the year. Figure 12-12 shows the flow exceedance characteristics of Chimacum Creek. Exceedance curves show that the peak annual flow typically occurs in the December through April time frame during the rainy season. The lowest annual flows typically occur in September or October prior to the start of fall rains.

The second gage was installed by a volunteer group in the NW one-quarter of Section 11, T29W, R1W, downstream of confluence of the east and west forks of Chimacum Creek. The JCCD has measured streamflow to compile a rating curve while the City of Port Townsend downloads data from the gage and prepares estimates of streamflow. The drainage area at that gage is estimated to be 30.4 square miles. The period of record for the gage is 1998 to present. Figures 12-13 and 12-14 present graphs of recorded streamflow for 1998 and 1999, respectively.

12.3.3 Estimate of Water Use and Allocation

12.3.3.1 *Groundwater Use and Allocation*

Exhibit 11 (Appendix A) shows the spatial distribution of groundwater use in the Chimacum sub-basin. The total groundwater withdrawal, assuming a domestic use of 250 gpd, is 1,961 af/yr. Approximately 58 percent of this total use is estimated from water rights and claims for irrigation purposes, and is qualified as being "lower accuracy" data. The remaining 42 percent (823 af/yr) is based on various sources for domestic and commercial uses, and is believed to be relatively high quality data. Given the general reliance on septic systems in the sub-basin, the consumptive portion of these domestic and commercial withdrawals is likely to be much lower than the total amount withdrawn. In the Chimacum sub-basin, 22 groundwater rights have been issued for a total of 2,124 af/yr. The spatial distribution of groundwater rights is presented in Exhibit 8. Figure 12-15 presents a pie chart of groundwater rights by use and shows that approximately 53 percent of the total allocation is for municipal purposes followed by 37 percent for irritation and 8 percent for domestic multiple use.

Approximately 1,034 (exempt) single family wells are estimated for the Chimacum sub-basin, translating to a potential exempt allocation of 5,790 af/yr. However, only a small portion of this exempt allocation is likely to be actually put to use.

There are 3 water right applications in the Chimacum sub-basin, requesting a total Qi of 745 gpm. Exhibit 9 presents the locations of these applications, and Table 4-2 lists their stated purpose of use. Two applications are for irrigation, and the third is for domestic multiple use.

There are 158 groundwater claims in the sub-basin. Table 4-3 lists claims by use, and shows that 57 of these claims list irrigation as a principal use. Typically, only a portion of claims listing irrigation as a purpose-of-use list numbers of irrigated acres. In the Chimacum sub-basin, water use associated with the reported numbers of irrigated acres amounts to 348 af/yr. If each claim is also assumed to include a domestic use, total claimed groundwater can be estimated at about 506 af/yr. The portion of these claims that have been actually put to use, and would qualify for a water right, is unknown. A map of the distribution of groundwater claims is presented on Exhibit 10.

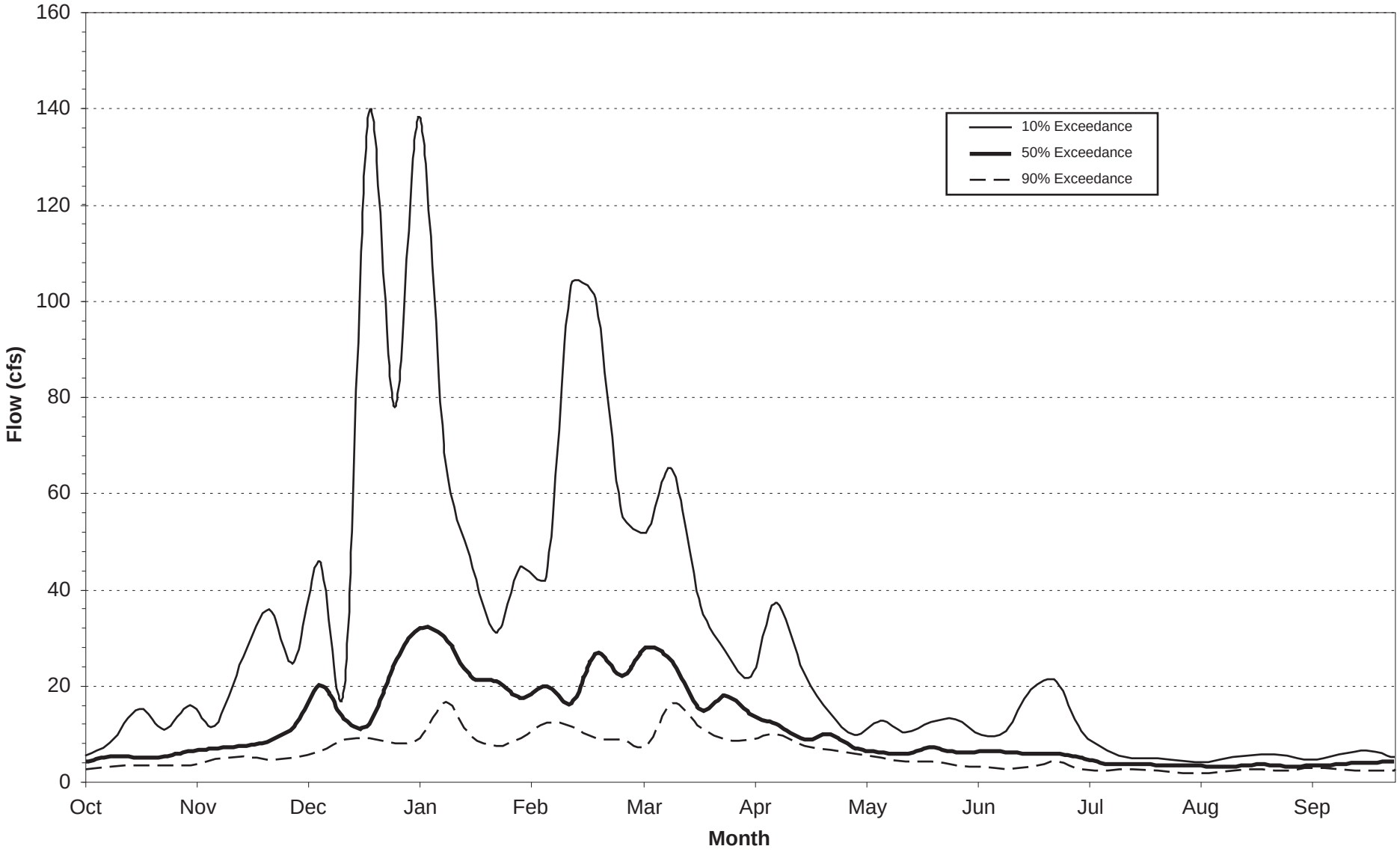
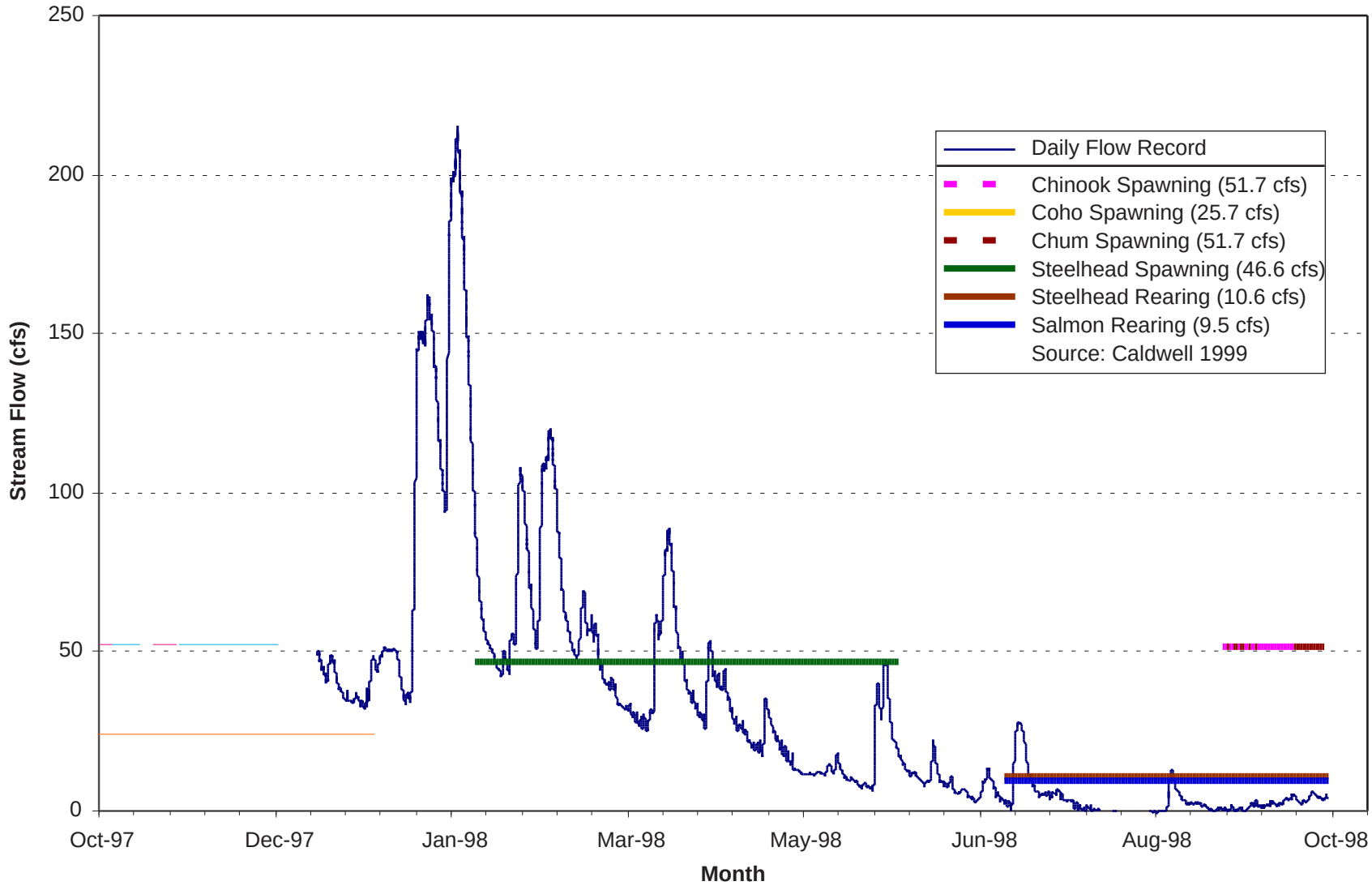
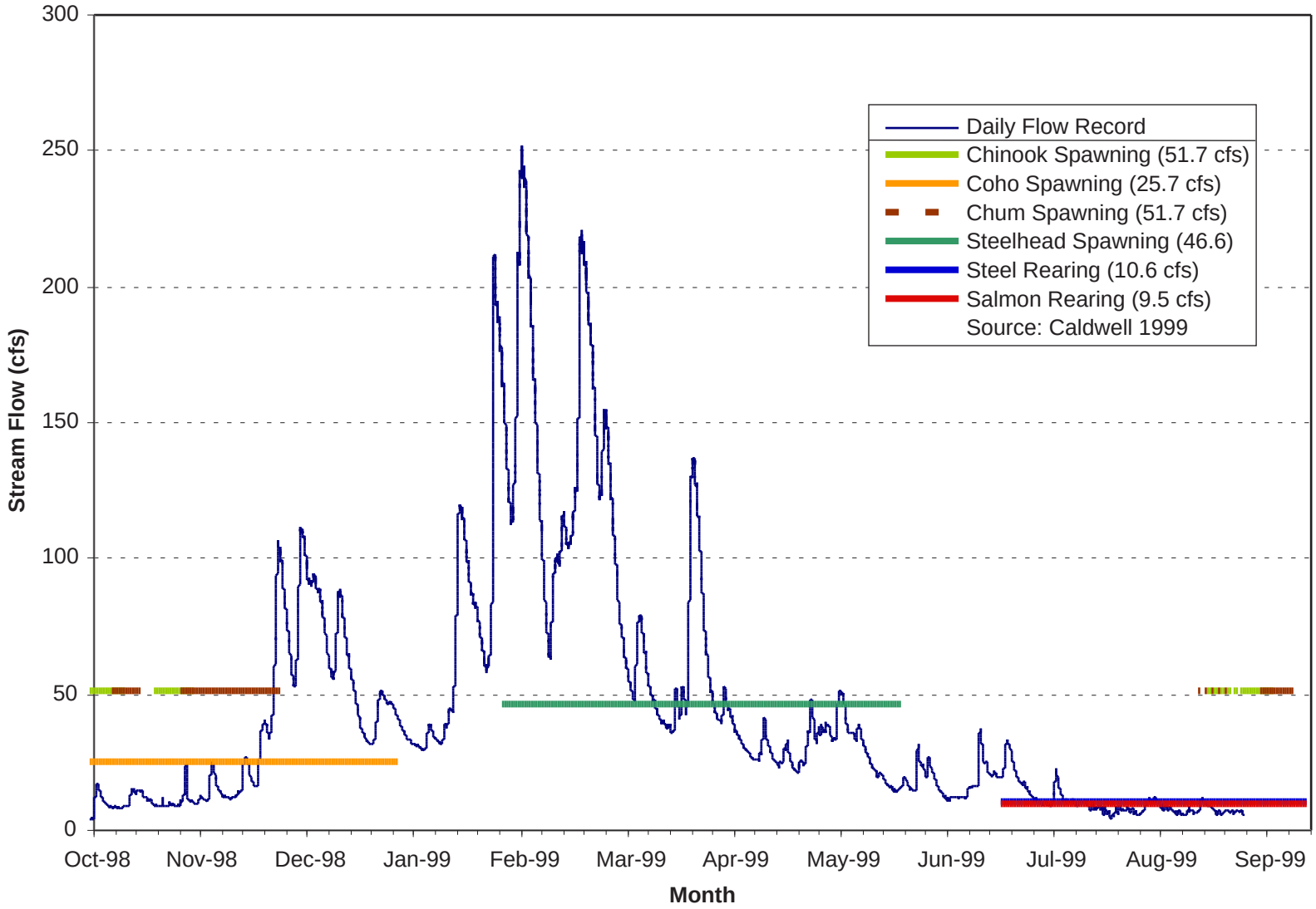


Figure 12-12
Flow Exceedance
Chimacum Creek, USGS Gauge 12051500
Period of Record 1952-1957



Source: JCCD flow data

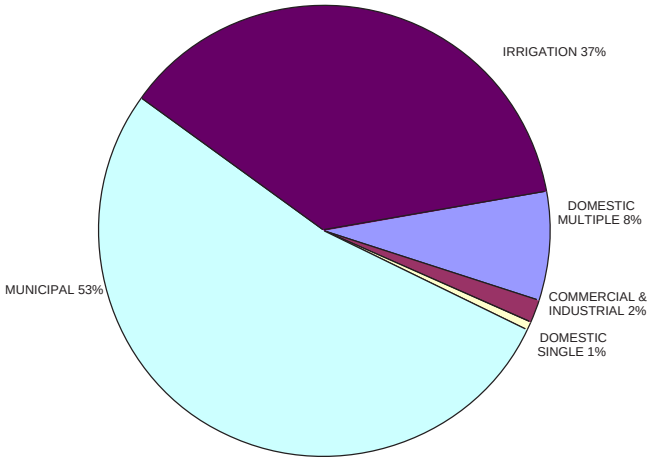
Figure 12-13
Theoretical Optimum Habitat and Flow, Chimacum Creek, Water Year 1998



Source: JCCD flow data

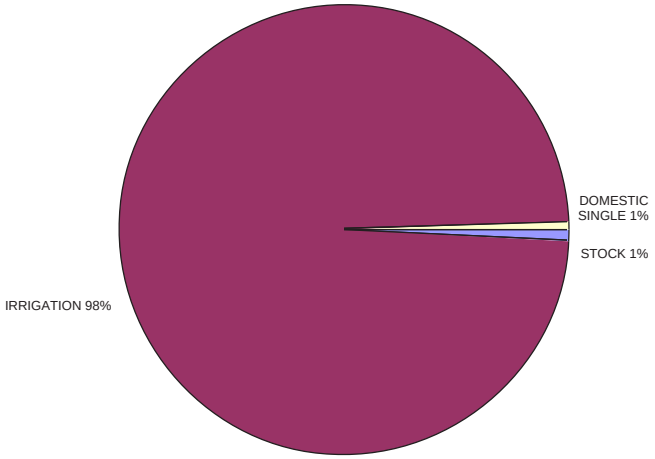
Figure 12-14
Theoretical Optimum Habitat and Stream Flow Discharge Chimacum Creek, Water Year 1999

GROUNDWATER RIGHTS (QA) BY USE



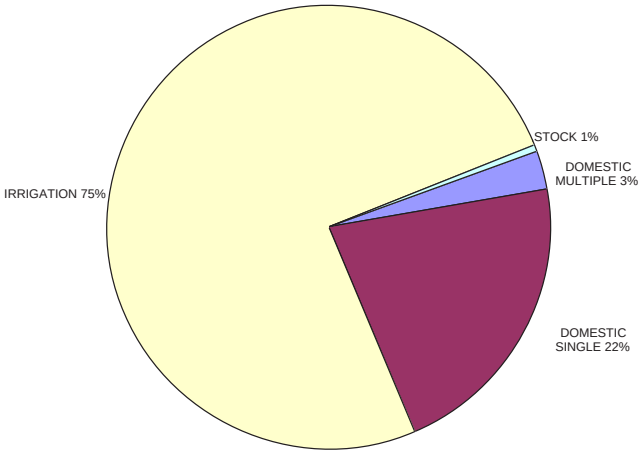
Note: total allocation = 2124 af/yr, accounted by use = 2124 af/yr, domestic exempt wells = 5972 af/yr

SURFACE WATER RIGHTS (QA) BY USE



Note: total allocation = 580 af/yr, accounted by purpose 580 af/yr, no non-consumptive rights as Qa

SURFACE WATER RIGHTS (QI) BY USE



Note: total allocation = 2.9 cfs, accounted by purpose = 4.5 cfs, additional non-consumptive rights = 1.2 cfs

Source: Ecology WRATs database

Figure 12-15
Chimacum Sub-Basin Groundwater and Surface Water Rights and Use, Consumptive Use Only

12.3.3.2 *Surface Water Use and Allocation*

Table 12-6 shows the relative distribution of consumptive use water rights in the Chimacum sub-basin. The largest use of water is for irrigation comprising 75 percent of the total instantaneous quantity and 98 percent of the total annual quantity. The next largest use is for domestic single use followed by domestic multiple uses and stock watering. Figure 12-15 presents pie charts of the relative distribution of surface water rights. The total consumptive use rights are 2.93 cfs and 580 af/yr annual quantity. Claims data indicate that 6.60 cfs are claimed with an annual quantity estimated at 702.6 af/yr. The claims data is not reflected on the pie charts. The spatial distribution of surface water rights (Qa), claims (Qi), and claims (Qa) are shown in Exhibits 13, 14, and 15, respectively.

Table 12-6. Analysis of Surface Water Allocation in Chimacum Sub-basin

Purpose	Percent Qi	Percent Qa
DM	3%	0%
DS	22%	1%
FR	0%	0%
IR	75%	98%
ST	1%	1%

Explanation of Purpose Codes:

CI	Commercial and Industrial Manufacturing	FS	Fish Propagation
DM	Domestic Multiple	IR	Irrigation
DS	Domestic Single	MI	Mining
MU	Municipal	ST	Stock Watering
FR	Fire Protection		

12.3.4 Hydraulic Continuity Potential

Relative hydraulic continuity potential (RHCP), as shown on Exhibit 17, is ranked as either “high” or “medium high” along most streams in the Chimacum sub-basin. This ranking is assigned because the stream valley has cut downward through the till into principal aquifer materials. On the middle reaches of Chimacum Creek, a “medium-high” ranking is assigned because lower-permeability bog deposits occupy the valley bottom and are likely reduce the hydraulic connection between the principal aquifer and the stream. RCHP is marked as “medium” in several areas where outwash and alluvial deposits overlie till, and “low” where streams cross over bedrock and till covered areas.

The Chimacum sub-basin is one case where hydraulic data were available for evaluation of the connection between groundwater and surface water. The City of Port Townsend’s “Sparling Wellfield” is located about a half mile west of the main stem of Chimacum Creek, and is completed in Vashon advance outwash deposits of the principal aquifer system. Low permeability bog or peat deposits are absent in this part of the Chimacum Valley. A 24-hour pumping test was conducted in the well, and water-levels were recorded in three monitoring wells (CH2M Hill 1996). The test results indicated the presence of a sub-surface, impermeable (or low permeability) boundary, and did not show significant evidence of dominant hydraulic connection with a surface-water body (e.g. Chimacum Creek). Hydrogeologic cross-sections prepared in the wellfield vicinity, and geologic logs from the monitoring wells, did not indicate the presence of any laterally extensive confining unit between the well completion zone and the land surface, however discontinuous occurrences of silty materials were noted. Groundwater in the principal aquifer was also noted as flowing to the east, towards the creek and Oak Bay.

The data show that the hydraulic connection between the completion zone for the Sparling Well and Chimacum Creek is not "high". The fact that the pumping test did not show a dominant stream influence suggests that seepage from Chimacum Creek does not dominate capture for the wellfield. It is likely that the presence of subsurface silt stringers and (possibly) a low streambed conductance reduces hydraulic continuity between the pumped zone and the creek. However, some degree of hydraulic continuity cannot be ruled out. The relatively coarse-grained materials between the land surface and the pumped zone suggest this potential, and the pumping test response to the impermeable (bedrock) boundary to the east may mask evidence of some hydraulic connection with the stream. Additional monitoring of pumping withdrawals, groundwater levels, and stream baseflow would be required to better estimate the degree of limited hydraulic continuity at the site.

Interpretation of the pumping test data shows how hydrogeologic analysis can improve understanding of hydraulic continuity where data are available and be used to direct further investigations to estimate the impacts of pumping. The interpretation presented above also reveals how areas ranked with a high RHCP can differ from this general prediction due to actual sub-surface conditions. The results of the pumping test interpretation do not preclude the possibility for other wells, completed in different (e.g. shallower) portions of the principal aquifer system, to exhibit a high continuity with Chimacum Creek.

12.4 HABITAT

12.4.1 Salmonid Distribution

Coho salmon, steelhead, and cutthroat trout inhabit Chimacum Creek. Native summer chum salmon were present, but were extirpated in the mid-1980's, then re-introduced in 1996. Fall chum salmon have been observed spawning in the lower reaches of the creek, but it is not known whether they comprise a self-sustaining population. Resident cutthroat trout are present in the upper drainage, but their status is unknown.

12.4.1.1 *Summer Chum Salmon*

Summer chum salmon in Chimacum Creek were extirpated in the mid-1980's. There are few replicated historical surveys from which the historic abundance of summer chum salmon can be described. Some spawner counts exceeded 100 (R. Lowrie, Chimacum High School cited in Lichatowich 1996), but WDFW surveys between 1974 and 1983 counted fewer chum salmon. No spawners were observed from 1994 – 1998. Summer chum salmon were reintroduced into Chimacum Creek in 1996, as fry which were reared from broodstock collected from Salmon Creek. In 1999, about 50 adults returned to Chimacum Creek, which were assumed to be the initial return from the re-introduction (Ames 2000 personal communication).

12.4.1.2 *Coho Salmon*

Coho salmon spawn and rear in suitable patches of habitat, primarily in the upper watershed, as the lowland channels have been severely degraded. Spawning distribution is limited by culvert blockages. The Upper West Fork supports the most concentrated spawning use. Coho salmon inhabit most of the mainstem and tributaries during the summer, but do not access the upper watershed above impassable culverts on the Swansonville tributary on the East Fork, and on the Barnhouse tributary on the West Fork. Putansu Creek provides limited spawning and rearing habitat. Juvenile coho salmon are rare during the summer in the channelized West Fork, probably due to degraded water quality. During the summer, rearing coho salmon are most abundant in higher tributaries, particularly in headwaters of West Fork, but

also in East Fork headwaters, and at the confluence; they are least abundant in reaches in the lower valley (Bahls and Rubin 1996).

Of the several lakes in the Chimacum basin, only Gibbs Lake is accessed by coho salmon. Its outlet stream, Naylor's Creek dewaters upstream of the West Valley Road during the summer, but spawning coho salmon have been observed above that point, and juvenile coho salmon have been caught in Gibbs Lake (Bahls and Rubin 1996). An impassable falls blocks access to Anderson Lake. Adult coho salmon ascend the outlet stream from Peterson Lake to within 0.5 miles of the lake, but further access is blocked by high gradient.

State and tribal staff conduct spawning surveys from RM 8.3 to RM 10.2 in the upper West Fork to estimate spawning escapement in Chimacum Creek. From 1984 to 1999, cumulative total redd counts have been below 100, except in 1998 when the count approached 200 (Figure 12-16). Supplemental surveys in 1998 observed 53 more redds higher in the West Fork (RM 10.2 – 10.7) and in tributary 17.0213. Coho salmon spawners were observed in the outlet stream of Gibbs Lake, the only lake they are known to access in the system (Bahls 2000 personal communication). Assuming that one female builds each redd, and a 50:50 sex ratio, the number of adult coho salmon spawning in Chimacum Creek has generally been 250 or less, and 500 in 1998 (Cooper XXXX personal communication). Higher escapement in 1979 and 1980 was probably the result of prior hatchery supplementation (McHenry et al. 1996).

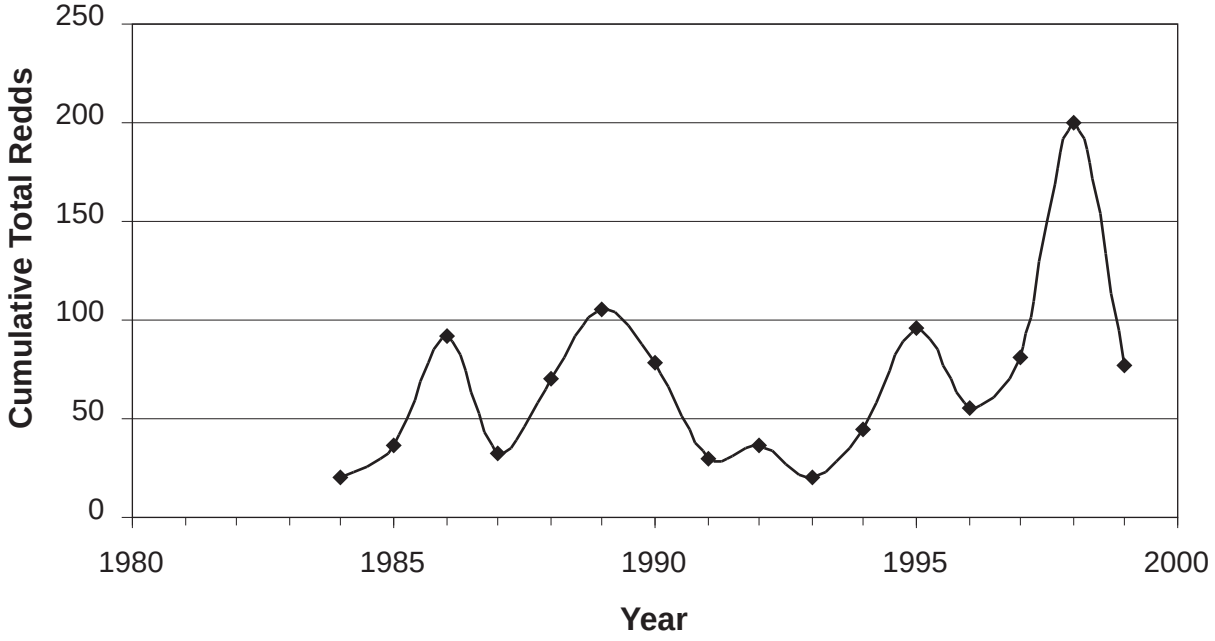
During supplemental surveys of a reach near the mouth (RM 0.2 – 0.6), a reach above the confluence of the forks (RM 2.7 – 3.0), and in a of the upper East Fork (17.205), (Bahls 1994, 1995, and 1996) observed up to 16 coho salmon in the upper tributary, and up to 30 near the mouth. Adult coho salmon were seen above the beaver dams present at RM 0.6 in 1995, so the dams are apparently passable at high flow. A survey of tributary 17.202 observed no coho salmon.

Coho salmon reared at the Dungeness and Quilcene hatcheries have been outplanted into Chimacum Creek. However, the stream has not been stocked in recent years. Analysis of a very small sample of scales collected from carcasses in 1994 confirmed the presence of hatchery-origin coho salmon (Bahls 1998). Coho salmon reared at the Port Gamble and Quilcene Bay net pens stray very infrequently into the Chimacum system.

Concern over the status of coho salmon in this region has been growing among resource managers, particularly when escapement was alarmingly low in the early 1990's. Though escapement has increased in recent years, it is thought that degraded freshwater habitat, high harvest rates, and poor marine survival depress production to a critical level (Bahls and Rubin 1996; Lichatowich 1993a; McHenry et al. 1996; PSSSRG 1997).

12.4.1.3 *Other Salmonids*

Supplemental surveys (Bahls 1995, 1996) observed few fall chum salmon near the mouth of Chimacum Creek in 1994 and 1995. Juvenile chum salmon were observed in Naylor's Creek in the summer of 1994, a tributary of the upper West Fork, suggesting that spawning may occur in that vicinity. Steelhead and anadromous cutthroat were also observed occasionally during these surveys. The status of winter steelhead in this stream is unknown. Resident cutthroat are also present in the upper drainage.



Source: R. Cooper, WDFW, 2000 (personal communication).

Figure 12-16
Coho Spawning Escapement to Chimacum Creek

12.4.2 Habitat Assessment

The most detailed habitat surveys available for Chimacum Creek were completed by Bahls and Rubin (1996) in 1995. They also described the reference condition of habitat in the basin by reviewing a number of historical sources and interviewing long-time residents of the valley, and estimated the extent of habitat loss.

12.4.2.1 *Channel Condition*

The East and West Forks of Chimacum Creek have been extensively channelized. Channels are straight, with near vertical banks and narrow fenced buffers. There are few side channels or meanders. Channel substrate is primarily composed of fine sediment. The East Fork is largely a shallow riffle and the West Fork is a lower gradient (0 to 5 percent) slough. No LWD is being naturally recruited in these valley reaches, but restoration projects have placed LWD in several locations. Suitable pools are rare, especially in ditched and straightened channels.

In the headwater streams gradient is higher, but sediment loading is high and pools are small. Tributary streams in the headwaters dewater in summer, except Barnhouse Creek (the southernmost tributary of the West Fork), in which a spring maintains stable flow year round. Below the confluence of the forks, the mainstem is moderate gradient (1 to 4 percent). It flows through a forested glacial outwash plain, then falls through a confined ravine in which the stream forms pools and riffles. In this lower reach the channel substrate is a mixture of sand and gravel. LWD in the channel contributes to pool formation.

The lower mainstem sustains a chronic high sediment load from the degraded higher valley reaches, but this conditioned worsened acutely when the Irondale Road crossing collapsed in 1983.

12.4.2.2 *Riparian Zone*

Vegetation in the lowland valleys is predominately grass, willows, rushes, and some alder. A section of the Lower West Fork is periodically choked by reed canary grass. Most reaches in the lowland valley channel have no shade. Riparian zones in the headwaters are mostly forested with mixed deciduous and coniferous species, and some LWD is present in the upper reaches. Above RM 1.3 most of the riparian zone has been cleared. Where a buffer zone remains it is narrow (less than 66 feet wide) and forested by small-diameter, deciduous species. Below RM 1.3 the riparian buffer is more than 200 feet wide, and trees average 12 to 20 inches in diameter.

12.4.2.3 *Sub-estuarine Zone*

The sub-estuary at the mouth of Chimacum Creek is in good condition. There are no roads, jetties, or dikes encroaching on the small, 5.2 acre delta. Approximately 30 acres of the tidal marsh was filled in the late 1800's, and a road crosses this filled area (Ames et al. 2000). A small area of the delta has been used for log storage.

12.4.2.4 *Factors Limiting Coho Salmon Production*

Bahls and Rubin (1996) found that over 90 percent of the coho salmon rearing habitat in the mainstem and East and West Forks has been eliminated by alteration of the channel and drainage of wetlands. They found that only 6 percent of the historic summer rearing habitat, and 3 percent of the winter rearing

habitat, is still available. Due to channelizing of the lower valley reaches, overall channel length has been reduced by 25 percent. Approximately 29 percent of the summer rearing habitat, and 20 percent of the winter rearing area in the main channel were lost. This is likely an underestimate of loss, because the maps used to measure historic stream length already reflected human changes. The area that is currently flooded in summer and winter is greatly reduced from the 539 hectares estimated from historical sources. The only summer rearing swamp left is a small beaver pond on upper West Fork. Draining of ponds, wet prairies, and marshes, and channel straightening, has reduced the total area available for summer rearing by 95 percent. Including the loss of wetland, there has been a near-complete loss of summer habitat in the lower West Fork. The total area of winter rearing habitat in the stream channel, and in adjacent flooded areas has been reduced by 98 percent. Spawning habitat for coho salmon was apparently always limited. Bahls and Rubin (1996) estimated that 12 percent of the historic spawning habitat area has been lost due to blockages (culverts) and channelization in the tributaries.

The quality of remaining habitat is also severely degraded, relative to the historical reference condition. Wetland draining and channelization, removal of riparian vegetation, and agricultural practices have reduced the area and frequency of pool habitat, degraded water quality conversion (i.e. elevated temperature and nutrient levels, low dissolved oxygen), and reduced the production of invertebrate prey species. Forested tributaries have also declined in quality, though not to the extent of the lowland area, because of logging, sediment input, removal of LWD, and loss of pools. The primary habitat limiting factors are high summer water temperature, sediment loading, and loss of channel complexity.

As previously stated, suitable pool habitat is rare, particularly in the lowland valley reaches. The optimal pool size for summer rearing is 1.5 to 2 m wide, 2 to 7 m long, with a maximum depth of 0.5 to 1 m. Pool frequency is highest in the headwater tributaries and lower mainstem.

Coho salmon abundance is strongly related to pool availability, but water quality must be adequate. Water temperature was monitored from 1992 to 1994 at four sites in the Chimcacum system. The data showed frequent exceedence of Class A (18 °C) and Class AA (16 °C) standards, and even of the 20 °C threshold tolerance for salmonids. The summer of 1995 was cold and wet, so temperature was not so elevated. High summer temperature is directly related to the lack of riparian cover. Dissolved oxygen measurements ranged from 0.8 to 10.8 mg/l. Coho salmon were most abundant at sites where dissolved oxygen was above 8 mg/l, and were absent at four sites where levels were below 5 mg/l. Bahls and Rubin (1996) found juvenile coho salmon in small pool refuges characterized by suitable water temperature, dissolved oxygen, depth, and channel structure, even where unsuitable conditions existed upstream and downstream.

12.4.3 Limiting Factors for Summer Chum Salmon

Sediment load in the reach below RM 1.3 has had a high impact on spawning habitat. Sediment load derives in part from channel degradation in the valley reaches, but it was acutely worsened by the collapse of the Irondale Road crossing in 1983. Some improvement in substrate quality has been observed recently, but fines are still high (Ames et al. 2000).

Loss of wetlands, channel instability has had a moderate impact on spawning habitat in the lower mainstem, because peak flows higher, and of increased duration. The valley still buffers flood run off, but it releases water more rapidly than when beaver ponds were present. Increased impervious area around the Tri-Area (Chimcacum, Irondale, and Port Hadlock) has also increased runoff rates and peak flow.

Wetland loss and irrigation withdrawals have exacerbated naturally low summer flow, with moderate impact on spawning habitat and adult migration. The Department of Ecology has closed the basin to any further surface water diversion (Ecology 1998b).

Deforestation in the upper watershed probably contributes to the increase in water temperature in the valley reaches, but the relatively intact riparian zone below RM 1.3 miles helps to moderate temperature in this lower reach. Temperature data shows that class AA standards were exceeded in July, and at end of August, 1998, but temperature did not exceed the preferred range of chum salmon (12 to 14° C), so the impact is moderate to low. Dissolved oxygen levels at the mouth ranged from 9.3 mg/l to above 10 mg/l; The class AA standard is 9.5 mg/l. Though water quality is degraded in some respects, and close to the tolerance limits of chum salmon, effects on spawning habitat are now considered to be low because the peak of chum salmon spawning occurs in mid-September, when water temperature has begun to decline from the summer peak.

Overall, the small decline in the quantity of subestuarine habitat has had a low impact on rearing and migration of chum salmon.

12.4.4 Restoration Projects

Numerous, large-scale channel and riparian restoration projects have been completed in Chimacum Creek in recent years (Table 12-7). In addition, nearly three million dollars in funding has been secured from the USFWS, WDFW, and the Jefferson Land Trust for fee simple purchase and conservation easement acquisition to protect high quality potentially productive habitat refugia that were identified in the watershed restoration assessment. Bahls and Rubin (1996) concluded that habitat restoration should focus on, in descending order of priority, replacing impassable culverts, establishing vegetated riparian buffers in the East and West Forks, restoring rearing ponds and channels in the East and West Fork valley reaches, constructing pools in the East Fork, and enhancing spawning and rearing habitat in the headwater tributaries.

Table 12-7. Summary of Completed Restoration Projects in the Chimacum Sub-basin

Stream	Date	Restoration Type	Description
Chimacum Creek	1998	Geomorphology/Revegetation	Created a high water bench along 650 ft of channel, added LWD, replanted riparian zone at RM 5.98 – 6.13.
Chimacum Creek	1998	Geomorphology/Revegetation	Diverted stream into a by-pass channel to avoid active landsliding. Cleaned sediment basins and planted riparian trees at RM 9.38-9.40
East Chimacum Creek	1998	Geomorphology/Revegetation	Created a high water bench along 450 ft of channel, added LWD, replanted riparian zone at RM 0.65 – 0.74
Chimacum Creek	1999	Restoration	Headwaters
Chimacum Creek	12/30/1988	Riparian Fencing	Gunning property
Chimacum Creek	12/30/1988	Riparian Fencing	G. Huntingford property
Chimacum Creek	12/30/1988	Riparian Fencing	Yarr property
Chimacum Creek	12/31/1988	Riparian Fencing	Westergaard/Boggs property
Chimacum Creek	12/31/1993	Riparian Fencing	Vodder property
Chimacum Creek	12/31/1993	Riparian Fencing	Shaw property
Chimacum Creek	3/30/1995	Riparian Fencing	Brown property (Center)
Chimacum Creek	12/30/1995	Riparian Fencing	Barnhouse property
Chimacum Creek	12/30/1997	Riparian Fencing	Mustin property
Chimacum Creek	3/31/1998	Riparian Fencing	Brown property

Table 12-7. Summary of Completed Restoration Projects in the Chimacum Sub-basin (continued)

Stream	Date	Restoration Type	Description
Chimacum Creek	12/30/1993	Salmon Habitat Restoration	Shaw property
Chimacum Creek	12/30/1993	Salmon Habitat Restoration	Brown property (Center)
Chimacum Creek	9/30/1999	Riparian Fencing	P. Huntingford property, Chimacum Crk trib.
Chimacum Creek	9/30/1999	Riparian Fencing	Shaw property
Chimacum Creek	12/31/1999	Riparian Fencing	P. Huntingford property – ditch on Yarr property
Chimacum Creek	12/30/1997	Salmon Habitat Restoration	Mustin property .
Chimacum Creek	9/30/1998	Salmon Habitat Restoration	Schmidt property fish passage barrier and restoration project
Chimacum Creek	9/30/1998	Salmon Habitat Restoration	Christian Stream - implementation
Chimacum Creek	9/30/1998	Salmon Habitat Restoration	Christian barrier culvert replacement
Chimacum Creek	9/30/1999	Salmon Habitat Restoration	3 fish passage weirs - Barnhouse Project.
Chimacum Creek	4/30/1994	Riparian Planting	Eaglemount Sediment Basin plantings
Chimacum Creek	4/30/1995	Riparian Planting	Shaw property (Puttaansuu Creek)
Chimacum Creek	4/30/1996	Riparian Planting	Mustin property
Chimacum Creek	4/30/1999	Riparian Planting	Christian riparian planting
Chimacum Creek	7/30/1999	Riparian Fencing	Barnhouse Project Fencing (Peter Bahls)
Chimacum Creek	7/30/1999	Salmon Habitat Restoration	Barnhouse Project Stream Restoration (Peter Bahls)
Chimacum Creek	3/30/2000	Riparian Planting	Barnhouse Project Riparian Planting (Peter Bahls)
E. Chimacum Creek	12/31/1998	Salmon Habitat Restoration	Durgan Stream Restoration Proj. – Completed
E. Chimacum Creek	12/31/1993	Riparian Fencing	Pontius fence
E. Chimacum Creek	12/31/1989	Riparian Fencing	Flaherty fence - E. Chimacum Crk
E. Chimacum Creek	12/31/1991	Riparian Fencing	Doolittle Fence – E. Chimacum Crk
E. Chimacum Creek	6/30/1993	Riparian Fencing	Barth fence (trib)
E. Chimacum Creek	12/30/1996	Riparian Fencing	Salvatore fence
E. Chimacum Creek	12/31/1996	Riparian Fencing	Olson/Bishop fencing
E. Chimacum Creek	12/30/1996	Salmon Habitat Restoration	Olson/Bishop stream restoration project
E. Chimacum Creek	9/30/1999	Salmon Habitat Restoration	Scholz stream restoration project - E. Chimacum Crk.
E. Chimacum Creek	4/30/1997	Riparian Planting	Olson/Bishop riparian planting
E. Chimacum Creek	3/31/1998	Riparian Planting	Rip. plant, Olson/Bishop, E. Chim. Crk
E. Chimacum Creek	4/30/1999	Riparian Planting	Durgan riparian planting
E. Chimacum Creek	4/1/2000	Riparian Planting	Scholz Project Riparian Planting
Putaansuu Creek	1998	Geomorphology/Revegetation	Replaced three failed weirs, added LWD, revegetation at RM 0.38-0.50
Putaansuu Creek	1990	Stream Restoration	800 ft of channel restored at RM 0.38-0.50
Putaansuu Creek	12/31/1992	Riparian Fencing	Shaw Fence – Putaansuu Crk
Putaansuu Creek	12/30/1990	Salmon Habitat Restoration	Putaansuu Cr. Stream restoration
Putaansuu Creek	9/30/1998	Salmon Habitat Restoration	Putaansuu Cr. Stream restoration project planning
Naylors Creek	3/30/1995	Riparian Fencing	Linderoth property
Naylors Creek	3/30/1995	Riparian Fencing	Ammeter property
Naylors Creek	12/30/1993	Salmon Habitat Restoration	Short fish passage culvert replaced
Naylors Creek	12/30/1990	Riparian Planting	Short riparian plantings
Naylors Creek	3/31/1998	Riparian Planting	Riparian plant, Ammeter, Naylor Crk

Source: JCCD

Six restoration projects are planned for construction during the summer of 2000 or later in the Chimacum sub-basin:

- Acquire and restore nearshore habitat in the Chimacum Estuary. This project is co-sponsored by JLT, WOS, NOSC, and JCCD.

- Supplement Summer chum salmon between RM 0.0-0.5 of Chimacum Creek. This is the fourth year of an ongoing project funded by WOS.

- Reconfigure the East Fork of Chimacum Creek between RM 0.8-1.0 by adding LWD, fencing and native riparian vegetation. This project is sponsored by NOSC.

- Reconfigure the East Fork of Chimacum Creek between RM 1.2-2.3 by adding LWD, fencing and native riparian vegetation. This project is sponsored by JCCD.

- Replace a culvert and reconfigure the West Fork of Chimacum Creek between RM 5.75-6.25 by adding LWD and rock weirs. This project is sponsored by NOSC.

- Acquire and preserve forested land in the headwaters of the East and West Forks of Chimacum Creek. This project is sponsored by the Jefferson Land Trust.

12.5 INSTREAM FLOW

Ecology and WDFW (1999) present toe-width study results for Chimacum Creek (RM 2.0). Species and lifestages considered included chinook salmon, coho salmon, chum salmon and steelhead spawning, and steelhead and salmonid juvenile rearing (see Table 6-1). Study results for Chimacum Creek range from a low of 9.5 cfs for salmonid juvenile rearing to a high of 51.7 cfs for chinook salmon and chum salmon spawning. These results can be used to develop instream flow recommendations for the stream.

Hiss (1993) presents optimum instream flows for the Chimacum Creek mainstem and the West Fork of Chimacum Creek. Species and lifestages considered were chum salmon, coho salmon and steelhead spawning, and steelhead rearing, as appropriate. The East Fork of Chimacum Creek was determined to have no suitable measurement site (see Table 6-3).

12.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS

12.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity

At the time of this writing, the only data available to characterize or predict future changes in land use were the population projections presented in Chapter 1. For several types of land use (e.g. logging and agriculture), the lack of specific information regarding anticipated future changes makes it impossible to predict related impacts to groundwater and surface-water quantities. General discussion of the relationships between these particular land uses, streamflow and groundwater recharge is included in Chapter 4. However, it should be noted that the impacts of such land uses may be highly dependent on particular site characteristics.

The population projections, zoning patterns and provisional UGA planning, however, can be used to qualitatively predict changes in patterns of residential and associated commercial land use. Increased population requires increased paved surfaces for homes, driveways, roads, and commercial infrastructure. If approved as a UGA, residential densities in the Tri-Area could be sufficiently high to locally increase runoff and reduce groundwater recharge. While soils in the Tri-Area are relatively permeable, more information is required as to how projected UGA densities and soil infiltration capacities combine to

influence runoff, recharge and preferred stormwater management strategies. In the rural residential portions of the Chimacum sub-basin, little information is available to assess the effects of associated densities of impervious cover on groundwater recharge. However, conversion of forested lands to meadows and lawns may reduce groundwater recharge in these areas. The effect of population increase on groundwater and surface water withdrawals is presented in Section 12.6.3.

12.6.2 Sub-basin Population Growth

In 1996, the Chimacum sub-basin had 5,675 residents (Jefferson County 2000). Chimacum sub-basin population growth over the next 20 years is estimated at 1,573 residents (Jefferson County 1998). Based on existing zoning (refer to Exhibit 1), the majority of population growth (1,165 residents) will most likely occur in the Tri-Area of Kala Point, Irondale, Port Hadlock, and Chimacum Crossroads. Additional growth may also occur in the upper Chimacum Valley on land zoned for one dwelling unit per 10 or 20 acres

12.6.3 Potential Impacts of Growth on Water Demand

Population in the Chimacum sub-basin is expected to increase by 28 percent between 1996 and 2016. Assuming that an average residence contains 2.2 people and uses 250 gpd, the projected increase of 1,573 people will cause an increased water demand of approximately 200 af/yr. Groundwater is currently the principal source of residential supply for most of the sub-basin, and is predominantly withdrawn by the Tri-Area water system and exempt wells. Given that 75 percent of the growth is anticipated to occur in the Tri-Area, a similar portion of the demand will likely be met by the Tri-Area water system. If additional demand is met with the groundwater resource, estimated current groundwater withdrawals (1,803 af/yr for residential, commercial and agricultural purposes) would increase by about 11 percent. The increased demand also represents about 1.1 percent of estimated groundwater recharge, with current groundwater withdrawals estimated at 9.6 percent. However, as discussed in Chapter 4, comparison of groundwater pumping with recharge cannot be reliably used as a direct indicator of groundwater availability. Furthermore, it should be noted that additional groundwater recharge occurred in the sub-basin prior to 1998 due to import of surface water for residential supply from the Port Townsend water system.

Current and anticipated future residential reliance on septic systems in the sub-basin suggests that the consumptive portion of residential use is significantly less than the total residential groundwater withdrawal. Assuming that 87 percent of residential withdrawals are returned to the ground via septic infiltration (Solly et al. 1993), the actual increase in groundwater consumption would be on the order of 26 af/yr.

12.6.4 Potential Impacts of Land-Use and Growth on Habitat

Stream and riparian habitat in Chimacum Creek have been moderately to severely degraded by residential and agricultural development, so the production of summer chum salmon, coho salmon, and other salmonids is limited by a variety of factors, including water quantity and quality, and lack of suitable spawning and rearing area. Population is projected to increase 28 percent in the Tri-Area and south Chimacum valley area by 2016, suggesting that demand for water resources will rise and impervious surfaces will increase and intact land cover will be modified.

A great deal of effort has been directed to restoring stream and riparian habitat in the Chimacum Creek system. Projects have generally aimed at removing barriers to migration, excluding livestock from and re-planting riparian zones, and stream channel restoration. Water quality problems, which include high temperature, low dissolved oxygen, and elevated fecal coliform levels, will not be alleviated until a

significant recovery of the riparian zone is achieved. The stream channel in the valley reaches of the upper mainstem and the East and West Forks, has been so extensively modified (Bahls and Rubin 1996) that restoration of channel complexity, and pool habitat in particular, remains a very large scale undertaking. However, re-establishing bank cover, and adding channel structure artificially, may be successful in significantly increasing rearing habitat and coho salmon production potential. Acquisition of key sections of riparian habitat, or development of conservation easements, are integral parts of the restoration plan.

12.6.5 Conservation Options

Water conservation options that may be applicable to water users in the Chimacum Sub-basin are summarized below.

- Tiered Water Rate Structures
- Modification of Landscape Irrigation Practices
- Water Conservation in Water Supply Systems and Individual Homes
- Educational programs
- Water Conservancy Boards To Facilitate Water Rights Transfers

12.7 DATA SYNTHESIS AND INTEGRATION

Water quality, stream and riparian habitat in Chimacum Creek have been moderately to severely degraded by residential and agricultural development. Population is projected to increase 28 percent in the Tri-Area and south Chimacum valley area, suggesting that demand for water resources will rise. Groundwater use is currently estimated to be 1,550 af/y, which is 8 percent of the estimated annual recharge. The total of proven groundwater rights and estimated use from exempt wells (3,558 af/y) comprises 19 percent of the annual recharge. However, the extent to which groundwater withdrawal affects streamflow, particularly during the base flow period in late summer and early fall, is not quantified. Analysis of sub-basin geomorphology, in this assessment, suggests a high or moderately high potential for hydraulic connectivity throughout the Chimacum Creek drainage. Well test data from the Sparling field, however, suggests low connectivity. This data will require verification at other sites before concluding that moderate new development of groundwater will not significantly affect streamflow. The relationship between stream flow and the availability of spawning habitat for summer chum salmon (the species most affected by low flow) will also require quantifying.

Water quality problems, which include high temperature, low dissolved oxygen, and elevated fecal coliform levels, will not likely be alleviated until a significant recovery of the riparian zone is achieved. The stream channel in the valley reaches of the upper mainstem and the East and West Forks, has been so extensively modified (Bahls and Rubin 1996) that restoration of channel complexity, and pool habitat in particular, remains a very large scale undertaking. However, re-establishing bank cover, and adding channel structure artificially, may be successful in significantly increasing rearing habitat and coho salmon production potential. Acquisition of key sections of riparian habitat, or development of conservation easements, are integral parts of the restoration plan. The long-term success of this restoration effort will depend, fundamentally, on sound land-use practices that protect riparian corridors and water quality. The integrity of the riparian zone in the lower mainstem remains relatively intact as a model of what conservative land-use practices can achieve.

12.8 DATA QUALITY, GAPS AND LIMITATIONS

In addition to the general data gaps identified for the entire WRIA, the following specific data gaps have been identified for this sub-basin:

12.8.1 Water Quality

General data gaps and limitations are similar to those discussed for the entire WRIA. Specific data gaps for this sub-basin include:

- Inventory livestock and agricultural practices along the stream corridors, particularly between RM 3 and RM 9, and identify areas where these activities may be potentially impacting water quality.

The JCCD has an existing on-going water quality monitoring program in the Chimacum sub-basin. This program will help to track water quality conditions and trends.

12.8.2 Water Quantity

Water quantity data gaps have been identified for the entire WRIA and generally apply to the Chimacum sub-basin. The following additional definition of data gaps is based on consideration of currently existing data, and provides additional detail where possible:

- While some hydrogeologic characterization has been performed in the Tri-Area (e.g. City of Port Townsend Sparling Well), better hydrogeologic definition is required to understand hydraulic continuity in this area. Hydrogeologic characterization could better define the distribution of groundwater discharge between Chimacum Creek and marine bodies to the east, and the degree to which stratification in the aquifer systems distributes pumping impacts to these two potential discharge areas.

- Better definition of hydrogeologic conditions is required along the east and west forks of Chimacum Creek. The hydrogeologic role of bog deposits along the valley bottom(s) is important to understanding hydraulic continuity. Definition of principal aquifers, water levels and groundwater flow directions in the valleys and beneath adjacent till uplands will help define how groundwater discharge is distributed to the creeks and adjacent marine bodies.

- Development densities in the Tri-Area are expected to increase over time. Better understanding of site runoff characteristics, soil permeabilities, and opportunities for stormwater infiltration may reduce potential hydrologic impacts associated with increased development.

- Long-term streamflow data and calibration of the existing flow gage would help to provide a more accurate flow record.

- Prior to 1997, most of the water used in the Tri-Area was imported from surface water from the City of Port Townsend water system. By discontinuing this relationship, reliance on local groundwater has increased. If this is the case, groundwater level responses and streamflow data could be beneficial in understanding the function of the groundwater flow system. Sufficient data were unavailable to examine hydrologic responses at the time of this writing, but should be examined if they exist.

12.8.3 Habitat

- The potential for groundwater withdrawal from the lower valley and Tri-Areas to affect stream flow. This would include maintenance of a stream gauge network, as well as intensive well monitoring, and hydrologic modeling.

- The effect of winter peak flow on egg survival by initiating scour and deposition monitoring.

- Permanent water temperature monitoring stations to measure the effectiveness of riparian buffer restoration in moderating summer temperature extremes.

- Identification of remaining areas of relatively high quality stream habitat for protection and acquisition.

- Conduct life history studies to better describe the winter rearing habits of juvenile coho salmon.

- Catalog small unnamed streams that have potential to support cutthroat trout and possibly other salmonids.

12.8.4 Instream Flow

Instream flow data gaps for this sub-basin are the same as that identified for the entire WRIA. There is sufficient information to develop instream flow recommendations and to proceed with the setting of instream flows in most of the larger streams in the basin.

13. SALMON – SNOW SUB-BASIN

13.1 SUB-BASIN DESCRIPTION

The Salmon-Snow sub-basin generally drains east from the Olympic Mountains to the south end of Discovery Bay (Figure 13-1). The two main water features in this basin are Salmon and Snow Creeks, both of which originate near Mt. Zion. The Salmon Creek basin is approximately 18.8 square miles (Williams et al. 1975). Over 50 percent of the basin is underlain by till soils, and approximately 3,000 acres is covered by palustrine or estuarine wetlands, or hydric soils.

Historically, Snow Creek was a tributary of Salmon Creek and the confluence was approximately 0.6 RM upstream of Discovery Bay. However, Snow Creek was dredged and relocated to the east side of the valley and now discharges directly to Discovery Bay. Snow Creek has two main tributaries, Trapper Creek and Andrews Creek. Andrews Creek currently drains through Crocker Lake. However, historically this tributary drained to Lake Leland, which is part of the Little Quilcene drainage and Crocker Lake did not have an outlet. Surface water features for the Salmon-Snow sub-basin are summarized in Table 13-1.

Table 13-1. Surface Water Features in the Salmon-Snow Sub-basin

Main Water Feature	Tributary	Confluence	Ecology Class	DNR Class
Salmon Creek			Class AA	1
Snow Creek			Class AA	1
	Andrews Creek	RM 3.5	Class AA	2
	Trapper Creek	RM 6.4	Class AA	3

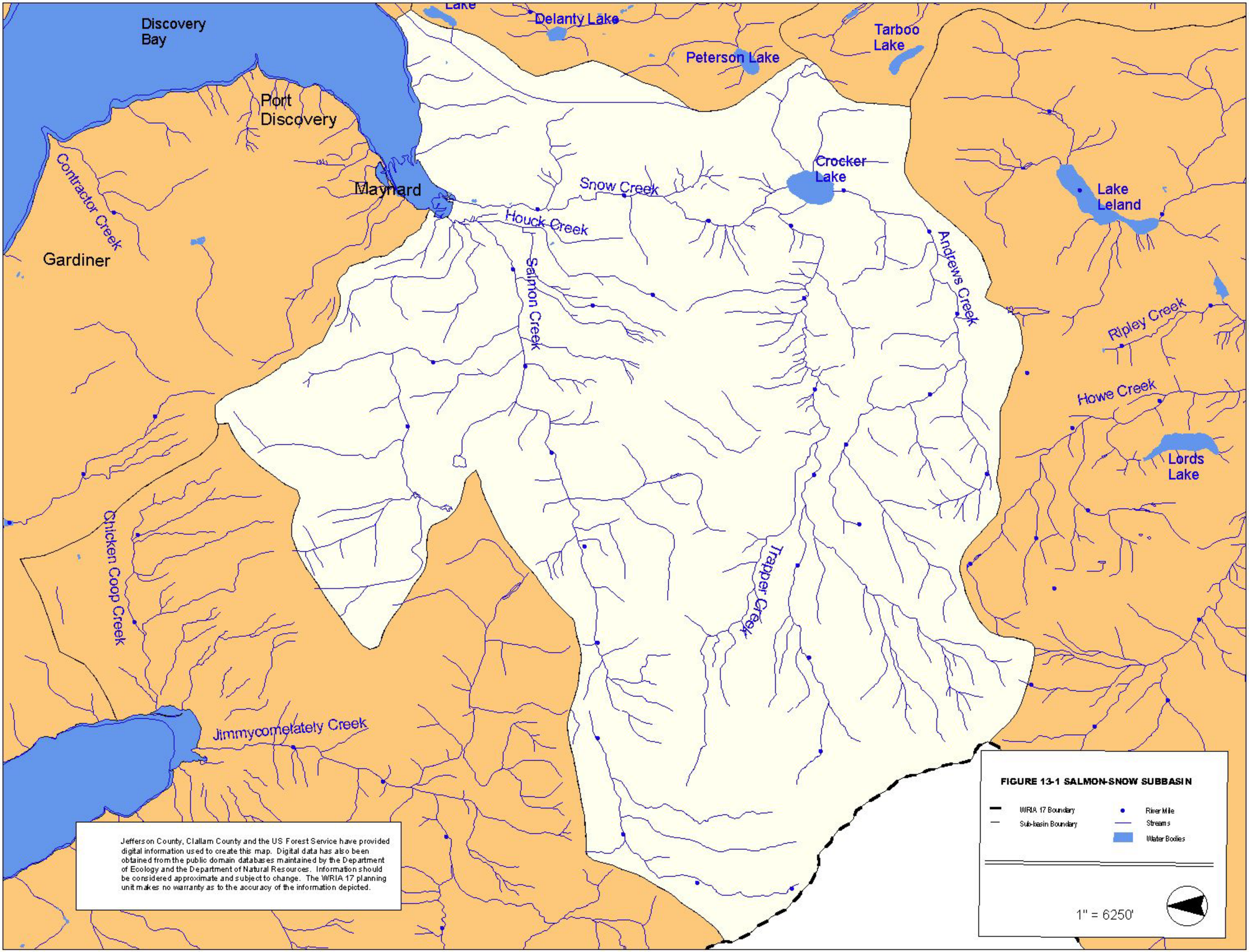
Source: Williams et al. (1975)

13.1.1 Surface Water Features

13.1.1.1 *Salmon Creek*

Salmon Creek flows into Discovery Bay, immediately west of the mouth of Snow Creek. Originally Salmon Creek was joined by Snow Creek at RM 0.6, but Snow Creek now flows separately to the estuary through an artificial channel. Salmon Creek has 8.7 miles of mainstem and 21.8 miles of tributary stream channel. The watershed drains 18.8 square miles, with headwaters on the northern slope of Mount Zion in the Olympic National Park. Most of the watershed is managed for timber production, the upper region under Forest Service or WDNR ownership, the middle region in private ownership. The dominant land use in the lower one mile of the valley is agricultural. Timber harvest began in the late 1800's, and much of the drainage was railroad logged in the 1920's. Logging of second growth timber resumed in the 1980's. Fires have periodically swept the area. A large fire burned in 1924. Because of these influences, 77 percent of the forest stands are immature (Bernthal et al. 1999).

The geology of the upper basin is predominantly basalt and glacial outwash. It is less vulnerable to mass wasting and erosion than the adjacent Snow Creek headwaters, because basalt and breccia underlies this upper canyon reach (SSWAT 1996). The lower valley is characterized by sand, gravel, and clay deposited during glaciation. Material transported from the upper watershed forms a broad alluvial fan (Bernthal et al. 1999).


Discovery Bay
Port Discovery
Maynard
Gardiner
Contractor Creek
Chicken Coop Creek
Jimmycomelately Creek
Delanty Lake
Peterson Lake
Tarboo Lake
Crocker Lake
Lake Leland
Snow Creek
Houck Creek
Salmon Creek
Andrews Creek
Trapper Creek
Ripley Creek
Howe Creek
Lords Lake
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
FIGURE 13-1 SALMON-SNOW SUBBASIN
WRIA 17 Boundary
Sub-basin Boundary
River Mile
Streams
Water Bodies
1" = 6250'

Timber harvest and road building have impacted salmon habitat heavily. Timber harvest rate in the Snow Salmon watershed has been 19 to 23 percent - higher than the generally accepted rate of 16 percent (Lichatowich 1993a). Road density 3.7 miles / square mile in the Salmon Creek basin (5 miles / square mile - Bernthal 1999 et al), and 2.9 miles/square mile in the Snow Creek basin, both of which exceed the threshold of 2.5 miles/square mile which is recommended to maintain salmonid habitat (Hall et al. 1992). Sediment loads are twice the background level, and peak flow may be 25 percent higher than what occurred prior to development (Lichatowich 1993a). Agricultural impacts from livestock grazing have degraded stream banks and water quality. Associated erosion problems were evident in 1950's (Lichatowich 1993a).

13.1.1.2 *Snow Creek*

Snow Creek drains a watershed of 23.1 square miles and includes 30 miles of mainstem and tributary stream channel. As stated above, Snow Creek formerly flowed into Salmon Creek at RM 0.6, but it was diverted into a dredged channel, east of Salmon Creek, and now flows separately to Discovery Bay. During high flow Snow Creek may still contact Salmon Creek through an old overflow channel. The average monthly stream flow is 22 cfs; extremes of 0.6 cfs and 1,309 cfs have been recorded. Average annual precipitation in the basin is 41.4 inches (McHenry et al. 1996).

The headwaters of Snow Creek are at 3300 ft on the slopes of Mt. Zion. The stream flows east through a confined valley then turns north into wide valley just above the confluence with Andrews Creek at RM 3.5. Andrews Creek originally flowed into Lake Leland, in the Little Quilcene sub-basin, but was diverted into Crocker Lake. An artificial outlet was created from the lake which now flows into Snow Creek (Ames et al. 2000).

The lower reaches of Snow Creek, from the mouth to RM 4.1, course through a wide alluvial valley. From RM 4.1 to 6.0 it is a V-shaped, more confined channel. Above RM 6.4 gradient increase markedly to 7 percent, and to 11 percent in the upper canyon reaches. The upper watershed is predominantly public and private forest land, but only 49 percent of the riparian zone below RM 3.0 is still forested. In this lower reach 30 percent of the land is in agricultural use, 11 percent is roads or dikes, and 5 percent is developed for rural residences (Ames et al. 2000).

13.1.2 Groundwater Features

Hydrogeologic characterization in the Salmon-Snow sub-basin is limited to existing maps of surficial geology. The groundwater flow system for the sub-basin is characterized by an extensive area of bedrock cover, localized till occurrence near Discovery Bay and on the western boundary of the sub-basin, and long, narrow alluvial or recessional outwash channels along streams. Exhibit 17 shows the generalized surficial geology for the area. The western portion of the sub-basin occurs in an area where digital geologic data were missing; however, review of geologic maps for the area shows that undifferentiated glacial deposits (not shown on Exhibit 17) occur along the upper reaches of Trapper Creek. Hydrogeologic characterization was unavailable to determine which principal aquifer materials may occur beneath the till-covered portions of the sub-basin.

13.1.3 Land Use

The two largest landowners in this sub-basin are the Federal Government (7, 700 acres in Olympic National Forest) and the Washington State Department of Natural Resources (6,700 acres) (SSWAT 1996). The Maynard area, located on Discovery Bay north of the mouth of Salmon Creek, is the main

residential area in the sub-basin. Land use is predominately commercial forest in the upper portions of this watershed and livestock rearing and hay production in the lower valleys.

Land use within Salmon Creek is primarily Olympic National Forest (9,230 acres) and privately held forest lands (5,052 acres). There is a mixture of agriculture (219 acres) and rural residential (613 acres) land uses in the lower watershed, with approximately 10 acres of land zoned for commercial uses located at the mouths of Snow and Salmon creeks along Highway 101 at the marine shoreline of Discovery Bay. The predominant residential zoning in this watershed (593 acres) is one residence per 20 acres.

Land use within the Snow Creek Watershed is similar to the Salmon Creek watershed, with additional rural residential land use in the lower watershed. The Olympic National Forest comprises 5,502 acres (38 of the watershed), and privately-held forest lands comprise 7,280 (51 percent of the watershed). Rural residential uses are zoned in 1,120 acres of the Snow Creek watershed, with 191 acres of zoned agricultural land. There are approximately 10 acres of land zoned for commercial use located at the mouths of Snow and Salmon creeks along the shoreline of Discovery Bay. The predominant residential zoning in this watershed (1,167 acres) is one residence per 20 acres (Jefferson County 2000). Land use in this sub-basin is shown in Table 13-2.

Table 13-2. Salmon-Snow Sub-basin Land Use

Description	No. of Parcels	Acres	% of Total
Rural Residential (1:5)	391	663	2.4%
Rural Residential (1:20)	194	1,667	6.0%
Olympic National Forest	11	14,732	52.9%
Rural Forest	29	738	2.7%
Commercial Forest	182	10,967	39.4%
Inholding Forest	17	627	2.3%
Commercial Agriculture	51	409	1.5%
Tidelands	23	104	0.4%
Roads and Right of Ways	65	304	1.1%
Totals	**963**	**27,839**	**100.0%**

Source: Jefferson County (2000) and Clallam County GIS (2000). Parcel data is for Jefferson County only.

13.2 WATER QUALITY

13.2.1 Surface Water Quality

Gately (1999) summarized water quality monitoring data collected in Snow Creek and Andrews Creek between June and October 1998. Temperature exceeded state standards at SN 0.2, SN 1.6 and AND 0.0 at least once during the monitoring period. Turbidity usually remained low. DO exceeded water quality standards at SN 0.2, SN1.6 and AND 0.0 at least once during the monitoring period; however, DO concentrations were never measured to be less than 8.0 mg/L in Snow Creek, which is the concentration at which salmonid production is thought to be impaired. The DO levels in Andrews Creek at the mouth were very low in August and September (4.8 and 6.4 mg/L, respectively), probably due to vegetative decay in the vicinity of Crocker Lake and warmer lake temperatures. DO levels improved at RM 1.6 in June and July 1999 (9.2 to 10.2 mg/L) from 1994 levels due to channel restoration work between RM 1.6 and 2.0 (Gately 1999). Surface water quality data for the Salmon-Snow sub-basin is shown in Table 13-3. Yemperature, DO, FC, and turbidity exceeded state standards for Andrews Creek and Snow Creek found in data collected by the JCCD (2000).

Table 13-3. Surface Water Quality Data Available in the Salmon-Snow Sub-basin

Survey Areas	Parameters						Years Sampled	No. of Sample Locations	Reference
	Temp.	Nutrients	DO	Turb	Cond.	FC			
Snow Creek	X	p	X	p	p		1998	3	Gately (1999)
Andrews Creek	X	p	X	p	p		1998	1	Gately (1999)
Snow Creek	X	p	X	X	p	X	1988,89, 95-2000	8	JCCD (2000)
Salmon Creek	p	p	p	X	p	X	1988,89, 95-2000	3	JCCD (2000)
Andrews Creek	X	p	X	X	p	X	1988,89, 95-99	39	JCCD (2000)

Note: nutrients = nitrate-nitrogen

X = water quality was exceeded for at least one sample

p = no water quality criteria was exceeded (passed)

Data from the JCCD water quality database are summarized in Table 13-4. Temperature, pH, and DO exceeded state water quality standards at eight stations out of 39 on Andrew's Creek. FC exceeded the standard at only one station (AND/0.0) which is downstream of Crocker Lake and agricultural land use.

Table 13-4. Water Quality Data Results for Salmon-Snow Sub-basin

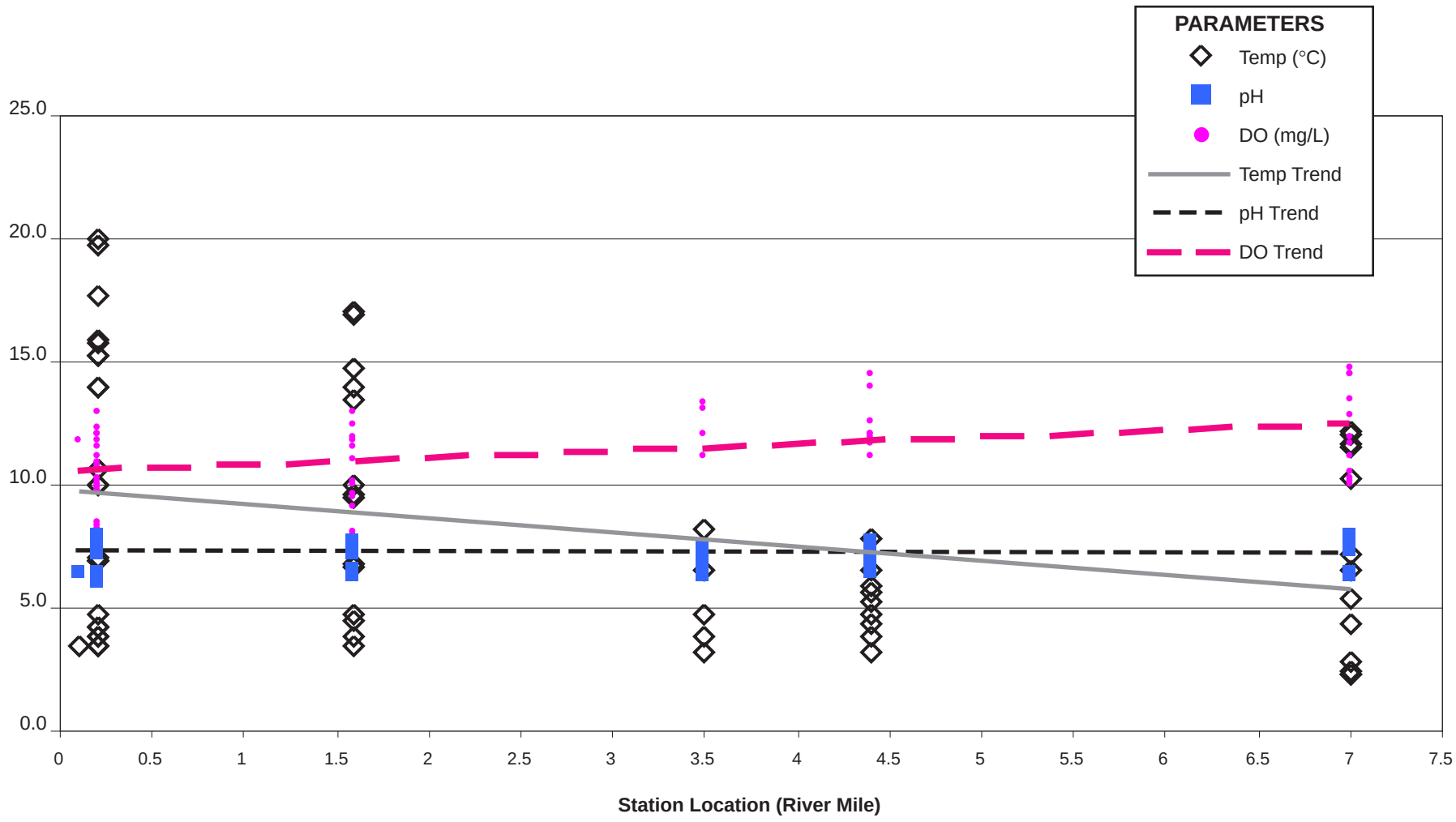
Area	Temperature (C)	pH	DO (mg/L)	FC (FC/ 100 mL)	Years Sampled
Salmon Creek	3.6 – 9.5	6.8 – 7.8	10.7 – 12.8	0 - 1450	1988, 89, 95-00
Snow Creek	2.3 - 20	6.0 – 8.0	7.9 – 14.8	0 - 1940	1988, 89, 95-00
Andrews Creek	2.4 – 21.6	5.7 – 7.6	0.1 – 14.7	2 - 266	1988, 89 95-99
Class AA Standard	<16.0	6.5 - 8.5	>9.5	Geo Mean <50 and <10% >100	

Source: JCCD (2000)

Temperature, pH, DO, and FC exceeded water quality state standards at three stations located between the mouth and RM 1.6 on Snow Creek. Figures 13-2 and 13-3 show water quality data on Snow Creek from the mouth to RM 7. In general, these figures show temperature increases from upstream to downstream, DO decreases, and pH remains about the same. FC counts increased from upstream to downstream as well, with very elevated counts occurring near the mouth.

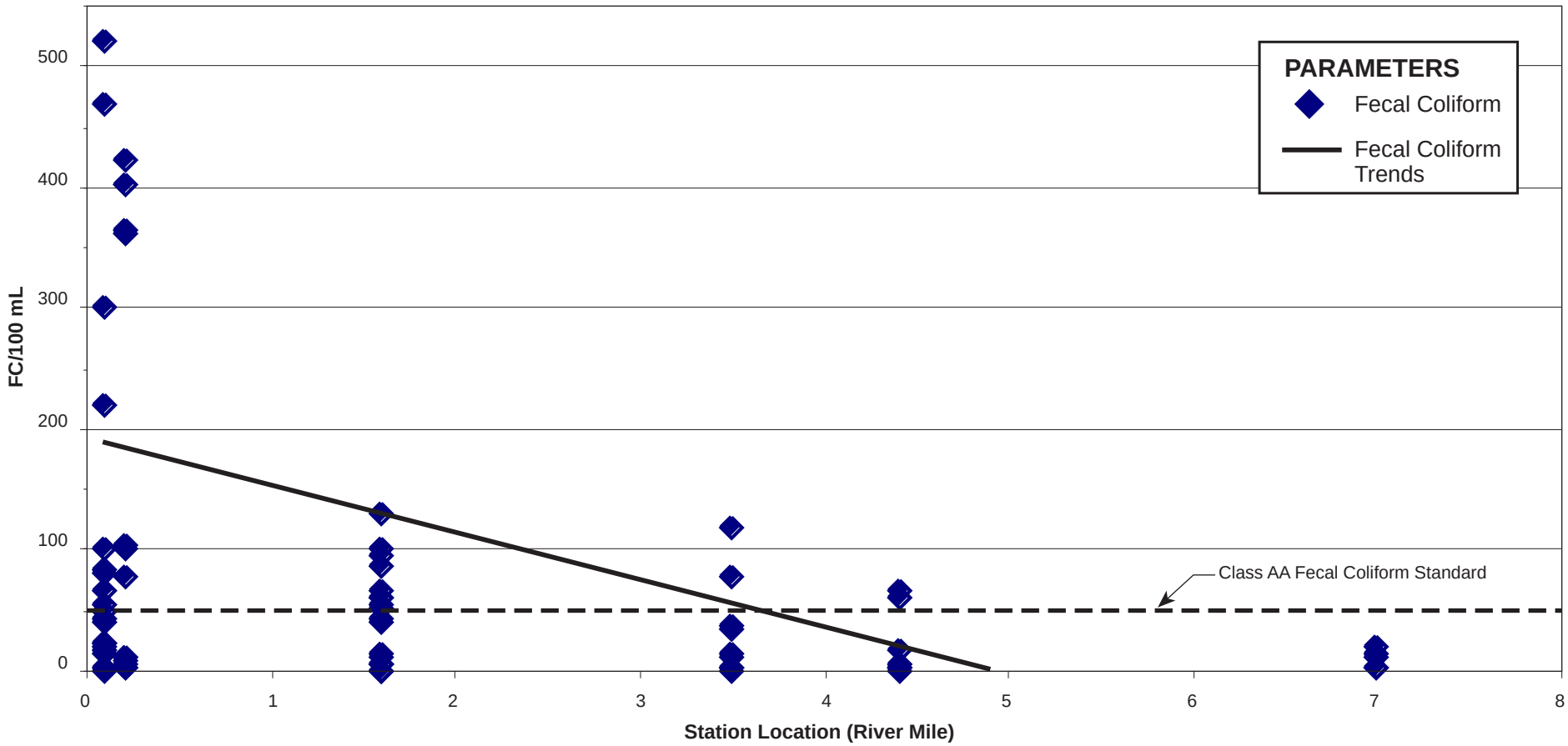
Temperature, pH, and DO were within state water quality standards at all three Salmon Creek stations. However, FC at station SA/0.0, located at the mouth, exceeded standards.

The SSWAT (1996) referenced a water quality study by Gately (1995) for Houck Creek, a tributary to Salmon Creek. Hillslope erosion, although subsided, has been a problem since the 1960's rerouting of the channel. Water temperatures downstream of a pond have exceded state standards with a maximum of 19.5 C. FC exceeded state standards in 1988 and 1989 in Houck Creek, with high bacteria counts in summer likely due to livestock use of adjacent pasture lands (SSWAT 1996). Data collected by JCCD (2000) has FC measurements for samples collected in 1988 and 1989 for two Houck Creek sites, HO1 (HO/0.0) and HO2. Geometric means for these two sites are 35 and 5, respectively, indicating that Houck Creek was below state standards for the JCCD data set.



Source: JCCD

Figure 13-2
Snow Creek Water Quality Trends, February 1988 – February 2000



Source: JCCD

Note: Two FC data points at Station 0.1 (1800 and 1940 colonies/100 mL) are off the scale and not included in the figure.

Figure 13-3
Fecal Coliform Trends in Snow Creek, February 1988 – February 2000

A study done by Jefferson County in 1994 indicated that Snow Creek accounts for 99 percent of the suspended sediment entering Discovery Bay, with most loading occurring during large storm events (SSWAT 1996). Bank erosion was noted as being common in DNR Type 4 and 5 streams that drain to Salmon and Snow Creeks in areas were timber harvesting and road building operations have occurred; both creeks have large deposits of fine sediment in the lower reaches (PSCRBT 1992).

Several studies, summarized below, measured FC concentrations in freshwater features of the basin. The Salmon-Snow sub-basin has experienced water quality exceedances for FC. It has been assumed that livestock and failing septic systems were the primary FC sources in the basin (PSCRBT 1992).

SSWAT (1996) summarize the findings of several studies that measured FC concentrations in the Salmon-Snow sub-basin. Studies done by Rubida (1989) and Gately (1995) as seen in SSWAT (1996) found that Snow Creek accounted for approximately 55 percent of the FC loading to Discovery Bay in 1989, and that this value increased to 80 percent in 1994. Similar studies done by Rubida (1989) as part of the 1988-1989 TFW ambient monitoring study indicate that Salmon Creek accounted for approximately 42 percent of total FC loading in Discovery Bay. Samples taken from Salmon Creek and Houck Creek exceeded State standards for FC in 1988 and 1989. Data collected during this period show that FC concentrations are high in the summer indicating that livestock may be the primary source.

Gately (1999) compared FC monitoring at two locations on Snow Creek and at the mouth of Andrews Creek between June and October in 1988, 1994 and 1998. The principle finding was that although Snow Creek still exceeded FC water quality criteria for Class AA streams in 1998, the geometric mean value (GMV) was much less than in previous years. The mouth of Andrews Creek (station AND 0.0) exceeded FC water quality criteria for Class AA streams, however the GMV at this station has also significantly decreased, which was attributed to a project that fenced approximately 1,000 feet of stream corridor immediately upstream of the sampling site. Table 13-5 summarizes these results. FC loading in Snow Creek and Andrews Creek have been reduced by approximately half since monitoring started in 1988 with Snow Creek decreasing from 58 billion/day to 27 billion/ day; and Andrews Creek decreasing from 12 billion/day to 7 billion/day.

Table 13-5. Salmon-Snow Creeks Fecal Coliform Monitoring Data

	Monitoring Year FC GMV (FC/100mL)		
Station	**1988**	**1994**	**1998**
SN 0.2	**186**	**469**	**86**
SN 1.6	–	46	24
AND 0.0	**141**	**197**	**51**

Bold = exceeds standard.
Source: Gately (1999)

13.2.2 Marine Water Quality

Water quality in Discovery Bay is generally considered good. The DOH performed a comprehensive sanitary investigation between 1993 and 1998 and approved over 9,000 acres of shellfish beds. No areas of Discovery Bay have been closed by DOH for shellfish harvesting (DOH 1999a). The results from DOH monitoring are summarized in Table 13-6.

Table 13-6. DOH Fecal Coliform Monitoring Results in Discovery Bay for 1993-1998

Station	Sub-basin	No. of Samples	Range	Geometric Mean	Meets Standard
1	Miller	31	1.7-15.0	1.9	Yes
2	Miller	31	1.7-110.0	3.0	Yes
3	Salmon-Snow	31	1.7-23.0	3.5	Yes
4	Quimper	31	1.7-79.0	2.6	Yes
5	Quimper	30	1.7-33.0	1.9	Yes
6	Quimper	31	1.7-17.0	2.0	Yes
7	Miller	30	1.7-2.0	1.7	Yes
8	Quimper	31	1.7-6.8	1.8	Yes
9	Miller	32	1.7-4.5	1.7	Yes
10	Quimper	31	1.7-7.8	1.8	Yes
11	Miller	30	1.7-7.8	1.8	Yes
12	Miller	31	1.7-4.5	1.9	Yes
13	Miller	31	1.7-23.0	2.1	Yes
14	Miller	31	1.7-23.0	1.9	Yes
15	Miller	31	1.7-4.5	1.7	Yes
16	Quimper	31	1.7-110.0	2.4	Yes
17	Quimper	32	1.7-2.0	1.7	Yes
18	Quimper	31	1.7-2.0	1.7	Yes
19	Quimper	31	1.7-2.0	1.7	Yes
20	Salmon-Snow	31	1.7-17.0	2.6	Yes
21	Quimper	31	1.7-13.0	2.2	Yes

Source: DOH (1999a)

Based on the DOH study, the southern portion of the Bay was considered a high threat area for shellfish harvesting because of local land use and the potential for water quality degradation (PSCRBT 1992).

13.2.3 Inventory of Potential Surface Water Contaminant Sources

Point and non-point sources of pollutants were identified based on the studies discussed above and data available from Ecology, the Forest Service, and existing studies.

Two NPDES point discharge locations have been identified in this sub-basin: Hammeren James and U.S. 101/SR 104 Drums (Ecology 1999a). It is noted that NPDES point source locations have been provided by Ecology and in some cases may depict facility names and locations that may not be entirely representative of existing conditions. The Ecology database does also not distinguish between stormwater and/or wastewater permits. No specific monitoring data or compliance problems were available for these specific point sources.

Forestry and agricultural operations such as livestock and hay production have been identified as the main potential sources of non-point pollution in the Salmon-Snow Sub-basin. Urban and residential use is sparse, and although failing septic systems and urban runoff occur within this sub-basin, they are not considered major sources of non-point pollution. FC and sediment, which are the two primary non-point pollutants identified, have been shown to be degrading water quality in the Salmon-Snow sub-basin and are summarized in Table 13-7 and are shown in Exhibit 3.

Table 13-7 Summary of Non-Point Source Pollution in the Salmon-Snow Sub-Basin

Location	Description of Pollutant
South side of North Skidder Hill	Clear cut in the late 1980's and is contributing large volumes of fine sediment to Snow Creek during large storm events (Jamestown S'Klallam 1994)
DNR Road	A DNR road that crosses Snow Creek has been identified as a significant sediment source (PSCRBT 1992)
Pasture below Uncas Road	Puget Sound River Basin Team observed that livestock have access to the channel at this location and are contributing FC directly to the creek (PSCRBT 1992; Nelson et al. 1992 as seen in SSWAT (1996)
Salmon-Snow Valley	PSCRBT identified 127 farm sites could be contributing to non-point source pollution (PSCRBT 1992)

13.2.4 Summary of Surface Water Trends and Compliance Problems

None of the fresh water features in the Salmon-Snow Sub-basin have been listed on Ecology's 303(d) list. However, several monitoring studies conducted on Salmon and Snow Creeks and their tributaries indicate that water quality criteria for Class AA streams is being exceeded.

Gately (1999) found that Snow Creek exceeded state water quality standards for Class AA streams for temperature and DO at RM 0.2 and 1.6, and exceeded FC criteria at RM 0.2 for samples taken between June and October in 1998. Rubida (1989) also found that FC in Snow Creek exceeded criteria for Class AA streams at a sampling station just upstream of Andrews Creek, and in Andrews Creek upstream and downstream of Crocker Lake at Hwy 101 sampling locations. Gately also compared water quality data from the mouth of Andrew's Creek and found that FC, temperature, dissolved oxygen, and turbidity criteria were exceeded. DO levels improved on Andrews Creek at RM 1.6 in 1999 compared to 1994 levels due to channel restoration work between RM 1.6 and 2.0 completed in 1995 (Gately 1999). Rubida (1989) found that FC concentrations in Salmon Creek measured at the mouth, just below Uncas Road, and at the mouth of Houck Creek did not comply with state standards for Class AA streams.

13.2.5 Groundwater Quality

Chloride concentrations in the Salmon and Snow Creek Sub-Basin are available for only nine wells (Exhibit 4). Natural background chloride concentrations are found in all but one of the wells. The single well with elevated chloride concentrations is located on Discovery Bay at the mouth of Salmon Creek. This well is one of three coastal wells in a sub-basin that includes only about three miles of shoreline.

Nitrate concentrations in the Salmon and Snow Creek Sub-Basin are shown on Exhibit 5, and are limited to ten wells. Three of these wells show nitrate concentrations exceeding background concentrations.

No incidents of anthropogenic groundwater contamination have been diagnosed in the Salmon and Snow Creek Sub-Basin.

13.3 WATER QUANTITY

13.3.1 Groundwater Quantity

Groundwater recharge estimated for the Salmon-Snow sub-basin is approximately 9,460 af/yr, and averages 4.1 in/yr over the entire area. This relatively low rate of predicted recharge is largely controlled by the presence of bedrock, which covers about 72 percent of the sub-basin. Exhibit 6 shows that recharge in non-bedrock areas varies from 10-15 in/yr over glacial till, to 10-25 in/yr in areas without till

cover. Precipitation averages 35.5 in/yr over the sub-basin, and is likely to cause moderate rejected recharge (runoff) from till covered areas. In places, a portion of this runoff is expected to infiltrate into local outwash/alluvial deposits and supplement recharge to shallow aquifers.

13.3.2 Surface Water Quantity

Longer-term stream gage records were only available for Snow Creek at the USGS gaging station located in Section 2, T28N, R2W. The drainage area at the stream gage is 11.2 square miles. Analyses of the stream gage records were performed to determine how streamflow has varied historically throughout the year. Figure 13-4 shows the flow exceedance characteristics of Snow Creek. The flow exceedance curves show that the peak annual flow typically occurs in the December through March time frame during the rain and snowmelt season. The lowest annual flows typically occur from August to October prior to the start of fall rains.

The theoretical optimum instream habitat and flow for the Snow River are plotted on Figure 13-4 along with the flow exceedance curves. The optimum chum salmon spawning flows are greater than the 10 percent exceedance values for Snow Creek during the months they are needed (September – October). The stealhead spawning flows are about the 10 percent exceedance value during the months they are needed (February – May). The optimum coho salmon spawning flows have exceedance values ranging from less than 10 percent in October to about 50 percent in December. The optimum flows for stealhead rearing have exceedance values ranging from 50 percent in July to less than 10 percent in September. It should be noted that the drainage area at the USGS gage is about one-half of the total drainage area of the Snow Creek watershed. Flows downstream of the gage would be higher than those shown in Figure 13-4.

13.3.3 Estimate of Water Quantity and Allocation

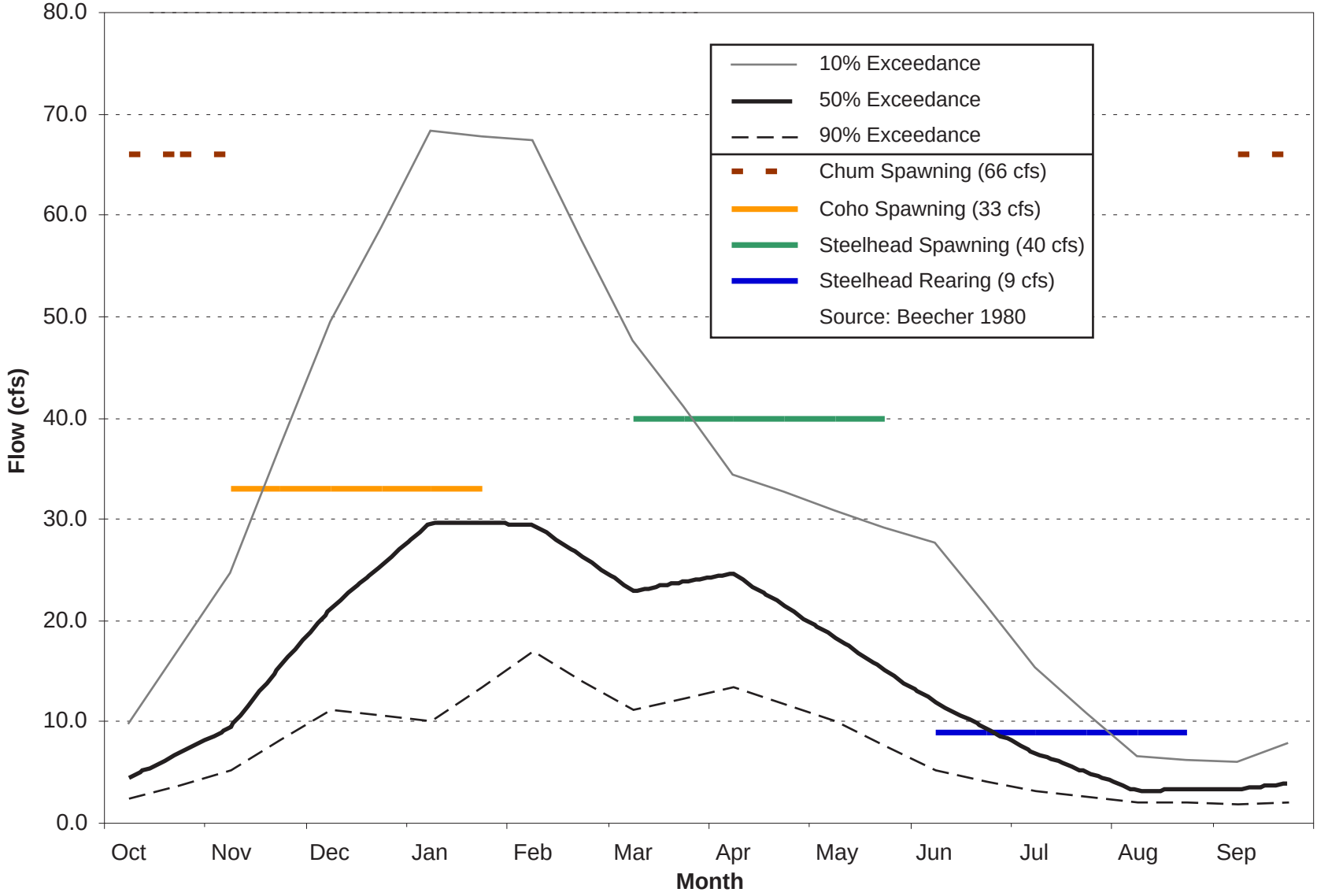
13.3.3.1 *Groundwater Use and Allocation*

Exhibit 11 shows the spatial distribution of groundwater use in the Salmon-Snow sub-basin. The total groundwater withdrawal, assuming a domestic use of 250 gpd, is 158 af/yr. Approximately 6 percent of this total use is estimated from water rights and claims for irrigation purposes, and is qualified as being "lower accuracy" data. The remaining 94 percent (148 af/yr) is based on various sources for domestic and commercial uses, and is believed to be relatively high quality data. Given the general reliance on septic systems in the sub-basin, the consumptive portion of these domestic and commercial withdrawals is likely to be much lower than the total amount withdrawn.

In the Salmon-Snow sub-basin, 2 groundwater rights have been issued for a total of 18.6 af/yr. The spatial distribution of groundwater rights is presented in Exhibit 8. Figure 13-5, a pie chart of groundwater rights by use, shows that 100 percent of the total allocation is for domestic uses.

Approximately 523 (exempt) single family wells are estimated for the Salmon-Snow sub-basin, translating to a potential exempt allocation of 2,930 af/yr. However, only a small portion of this exempt allocation is likely to be actually put to use.

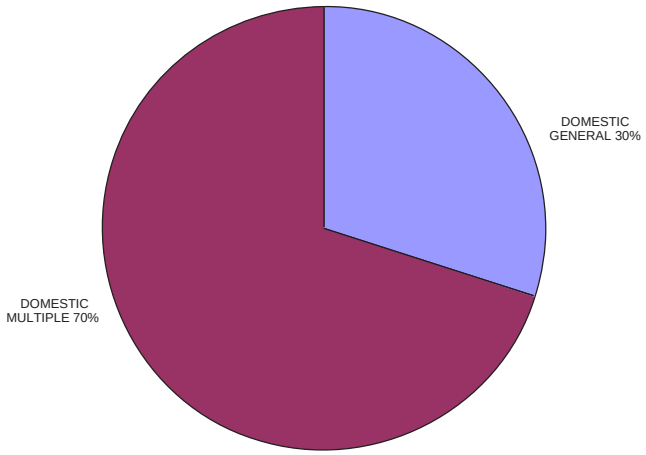
There are 34 groundwater claims in the sub-basin. Table 4-3 lists claims by use, and shows that 15 of these claims list irrigation as a principal use. Typically, only a portion of claims listing irrigation as a purpose-of-use list numbers of irrigated acres. In the Salmon-Snow sub-basin, water use associated with the reported numbers of irrigated acres amounts to 10 af/yr. If each claim is also assumed to include a domestic use, total claimed groundwater can be estimated at about 44 af/yr. The portion of these claims that have been actually put to use, and would qualify for a water right, is unknown. A map of the distribution of groundwater claims is presented on Exhibit 9.



Note: Drainage area size at gage is only 50% of total drainage area.

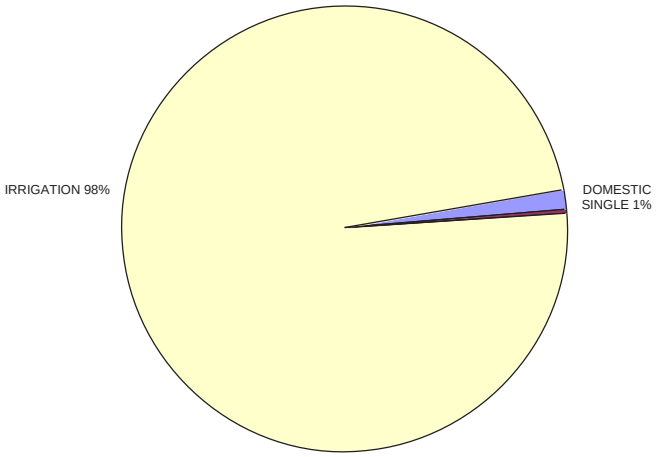
Figure 13-4
Theoretical Optimum Habitat and Flows, Snow Creek near Maynard
USGS Gauge 12050500
Period of Record 1952-1972, 1977-1984

GROUNDWATER RIGHTS (QA) BY USE



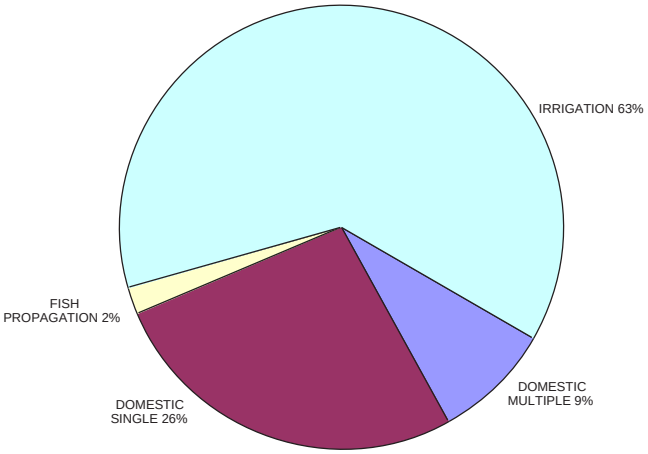
Note: total allocation = 19 af/yr, accounted by use = 19 af/yr, domestic exempt wells = 2930 af/yr

SURFACE WATER RIGHTS (QA) BY USE



Note: total allocation = 258 af/yr, accounted by purpose 318 af/yr, no additional non-consumptive rights as Qa

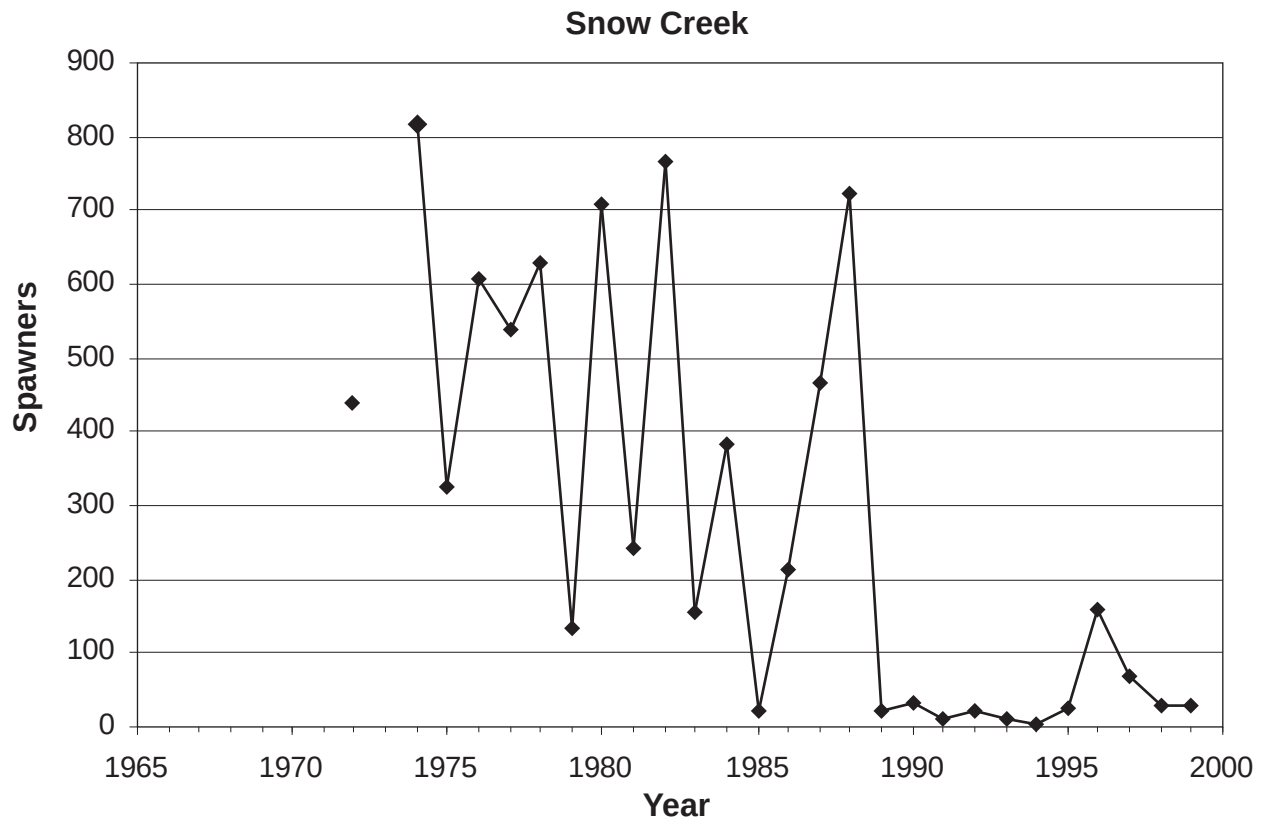
SURFACE WATER RIGHTS (QI) BY USE

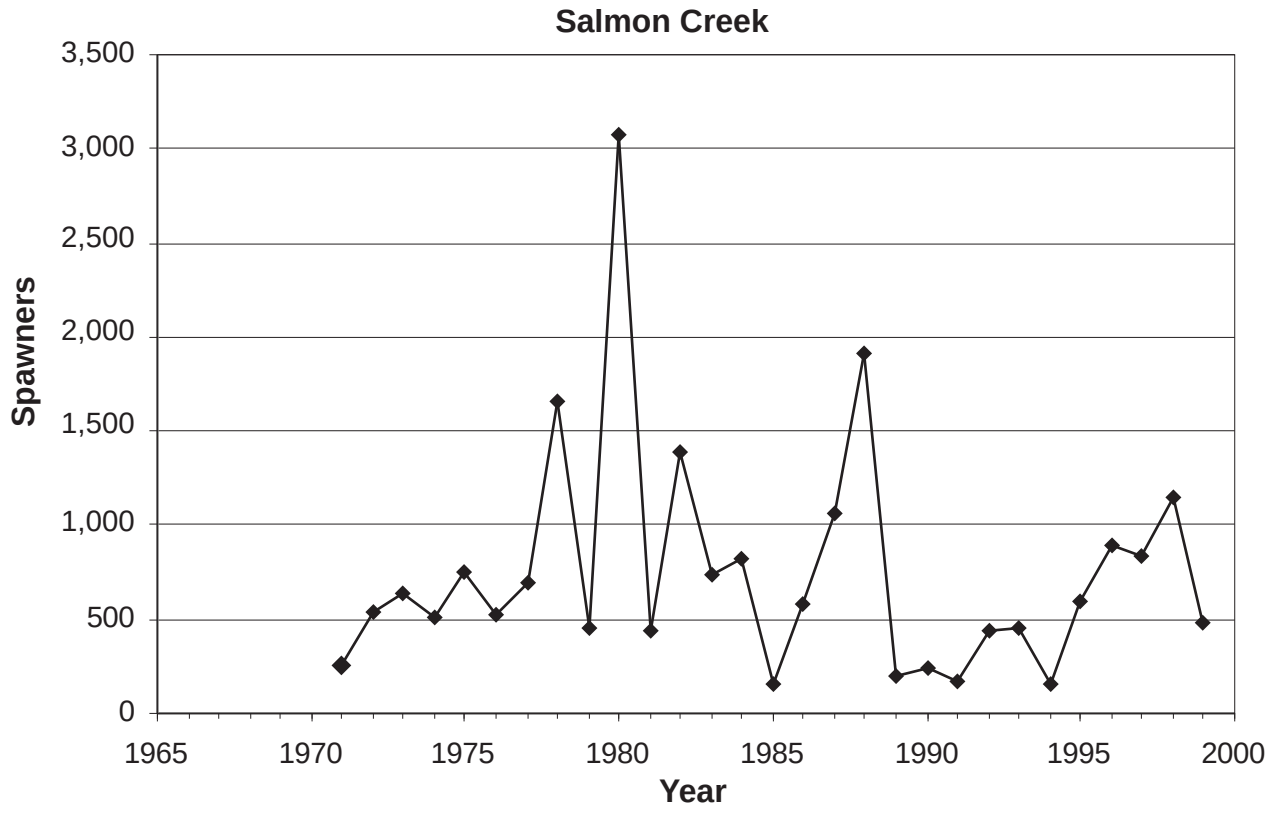


Note: total allocation = 1.6 cfs, accounted by purpose = 2.5 cfs, additional non-consumptive rights = 0.2 cfs

Source: Ecology WRATs database

Figure 13-5
Salmon-Snow Sub-Basin Groundwater and Surface Water Rights and Use





Source: Ames, et al., 2000.

Figure 13-6
Summer Chum Escapement to Salmon Creek and Snow Creek, 1973-1999

There are no water right applications in the Salmon-Snow sub-basin.

13.3.3.2 *Surface Water Use and Allocation*

Table 13-8 shows the relative distribution of consumptive use water rights in the Salmon-Snow sub-basin. The largest use of water is for irrigation needs, comprising 63 percent of the total instantaneous quantity and 98 percent of the total annual quantity. The next largest use is for domestic single households, followed by domestic multiple homes and fish propagation. Figures 13-5 presents pie charts of the relative distribution of water rights. The total consumptive use rights are 1.64 cfs and 258 af/yr annual quantity. Claims data indicate that 2.02 cfs are claimed with an annual quantity estimated at 192 af/yr. The claims data is not reflected on the pie charts. The spatial distribution of surface water rights (Qa), claims (Qi), and claims (Qa) are shown in Exhibits 12, 13, and 14, respectively.

Table 13-8. Analysis of Surface Water Allocation in Salmon-Snow Sub-basin

Purpose	Percent QI	Percent QA
DM	9%	0%
DS	26%	1%
FS	2%	0%
IR	63%	98%

Explanation of Purpose Codes:

CI	Commercial and Industrial Manufacturing	FS	Fish Propagation
DM	Domestic Multiple	IR	Irrigation
DS	Domestic Single	MI	Mining
MU	Municipal	ST	Stock Watering
FR	Fire Protection		

13.3.4 Hydraulic Continuity Potential

According to its definition, RHCP (shown on Exhibit 17) is ranked as “low” in the bedrock and till-covered areas that dominate the sub-basin and “medium” in the shallow alluvial and recessional outwash deposits present along streams. It is important to remember that the definition is biased towards hydraulic continuity with principal aquifers, and that continuity between thin alluvial sediments and adjacent streams may actually be high in an absolute sense.

13.4 HABITAT

13.4.1 Salmonid Species Distribution

The fish community include sculpins (Cottidae), Pacific lamprey (*Lampetra tridentatus*) and brook lamprey (*L. richardsoni*), summer chum salmon, coho salmon, steelhead, and resident and anadromous cutthroat, and sturgeon (SSWAT 1996).

Prior to settlement, fish distribution was likely similar to today, and was limited by gradient breaks, and perhaps intermittently limited by LWD barriers. In Snow Creek anadromous fish currently access 5.7 miles of the mainstem, and 6.5 miles of tributary streams. Coho salmon, steelhead, and anadromous cutthroat trout also spawn and rear in the middle and upper reaches. Resident cutthroat inhabit the upper

reaches at elevations of up to 1600 feet. Additional, more specific information about individual salmonid is provided below.

13.4.1.1 *Summer Chum Salmon*

Summer chum salmon that return to Snow Creek and Salmon Creek spawn from early September to mid-October. Spawning areas are primarily in the lower reaches of both streams, below Uncas Road (i.e. up to RM 0.6 on Salmon Creek, and RM 1.3 on Snow Creek). Some spawning occurs as far up as RM 1.6 on Salmon Creek, and to RM 3.2 on Snow Creek (i.e. the confluence of Andrews Creek) (PNTPC et al. 1999; SSWAT 1996).

Genetic analysis of summer chum salmon tissue samples collected from Snow Creek and Salmon Creek did not show a significant difference between the two populations, so they are classified as a single stock. It is of native origin, bit is now a composite of natural and artificial production. Its status is depressed. Spawning escapement to Salmon Creek has been relatively stable over the last nine years (Figure 13-6), with an increasing trend discernible from 1995 to 1998. Escapement to Snow Creek, by contrast, dropped extremely low in the late 1980's, and has been generally below 50 since 1989 (Figure 13-6). The slight increase in 1996 and 1997 may have been related to the contribution of the supplementation program, which is rearing Salmon Creek broodstock.

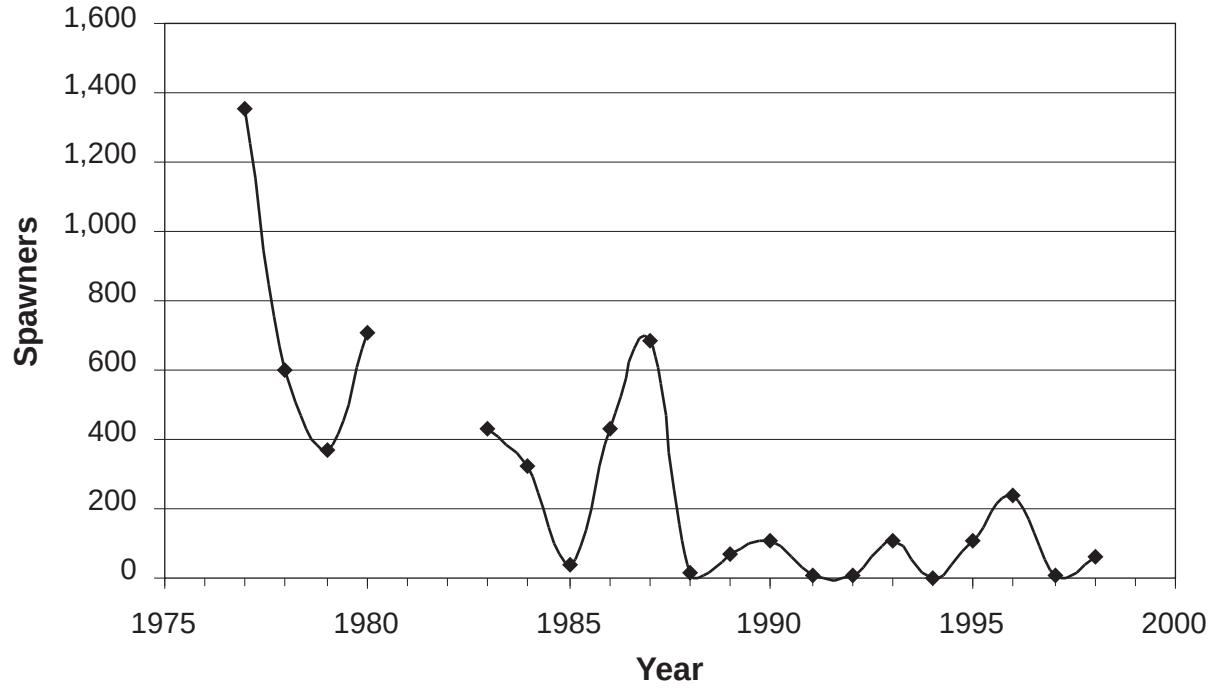
The effective population size for the Snow/Salmon aggregate was 3,057 for the period 1995 – 1998, with an increasing trend due to the increase in Salmon Creek escapement, so the current risk of extinction is low. However, for the period 1989 - 1991 average escapement was only 226, and the effective population size only 163. At this low level of abundance, and considering the degraded state of spawning and incubation habitat, the extinction risk was high (Ames et al. 2000).

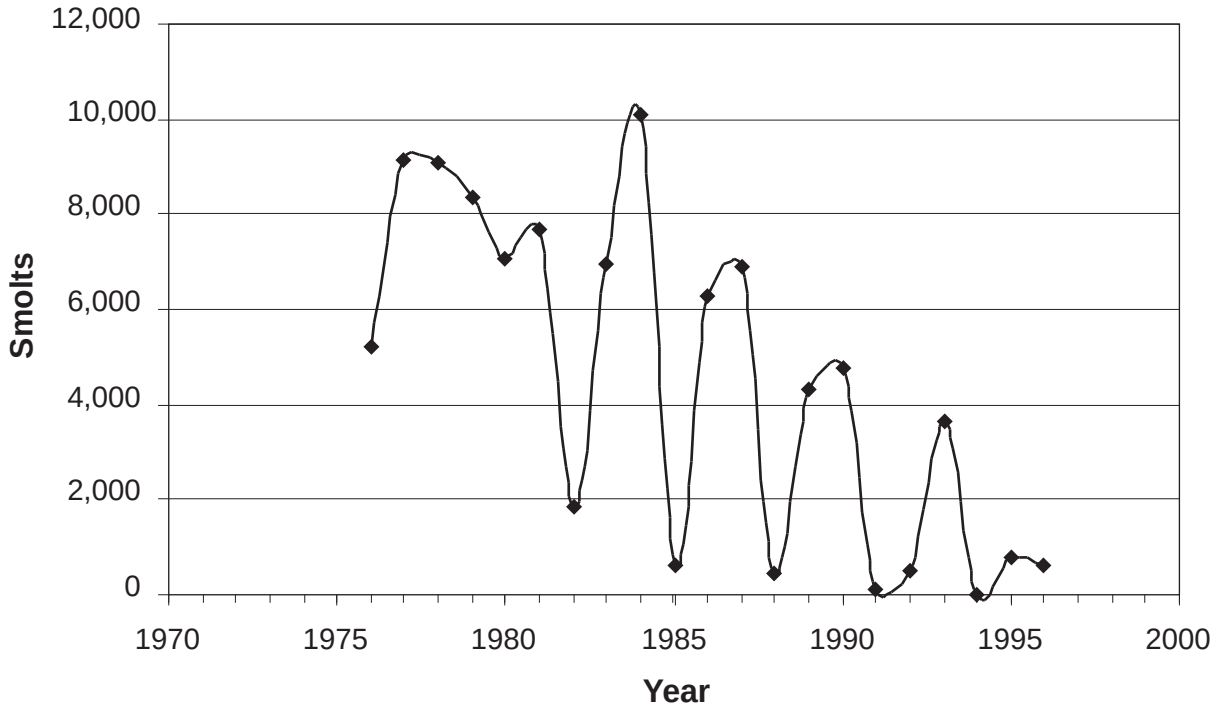
13.4.1.2 *Coho Salmon*

Although older sources placed the upper limit of coho salmon access at RM 4.9 (Williams et al. 1975), recent surveys have shown that coho salmon, steelhead and cutthroat access 7.5 miles of the stream, up to Crocker Lake and Andrews Creek (Lestelle et al. cited in McHenry et al. 1996).

Coho salmon spawn in the Snow / Salmon system between October and early January. Post emergent juvenile coho salmon rear for a year in freshwater, the emigrate as smolts from April through early June. The peak of the outmigration has occurred about the second week of May (Johnson and Cooper 1991). Coho salmon also return to Contractor's Creek, on the west shore of Discovery Bay, but the abundance in that system has not been determined.

Coho salmon in Snow Creek and Salmon Creek are considered a single stock, and are part of a management unit that includes stocks in Sequim Bay and Chimacum Creek. Spawning escapement and smolt production have been enumerated in Snow Creek since WDFW installed a weir on the system in 1976. Spawning escapement to Snow Creek has shown a long-term declining trend since the mid-1970's, and has been chronically low since 1988 (Figure 13-7), with five years below 20. Escapement of three year-old adults ranged from 400 to 1,300 between 1976 and 1987. Egg to smolt survival in Snow Creek has averaged just under 2 percent, with a long term average of about 40 smolts produced per female spawner (Johnson and Cooper 1993). By comparison, coho salmon egg-to-smolt survival in Big Beef Creek also averaged about 2 percent between 1989 and 1998, and ranged from 1 percent to 5 percent (J. Sawicki, PNPTC, pers comm). The escapement estimation methodology is being updated, but Salmon Creek is assumed to have escapement equal to Snow Creek, based on the area of suitable habitat (Crain personal communication). Smolt production from Snow Creek is also showing an alarming negative trend (Figure 13-7). Currently, stock status is considered to be critical (McHenry et al. 1996).





Source: Johnson and Cooper, 1995.
R. Cooper, WDFW, 2000 (personal communication).

Figure 13-7
Coho Spawning Escapement and Smolt Production in Snow Creek

A coho salmon supplementation project was initiated at the Snow Creek Research Station in the fall of 1999. Broodstock is collected at the weir, and eyed eggs are outplanted to remote site incubators at several sites in the Snow - Salmon system. Sub-yearling coho salmon are also released into the Snow Creek drainage as part of the supplementation project.

13.4.1.3 *Steelhead*

Steelhead are found up to RM 7.5 in Snow Creek (SSWAT 1996), though the falls at RM 6.5 may block higher access. The WDFW weir enables enumeration of steelhead escapement and smolt production. Adult escapement has declined from the level seen from 1975 – 1985, and has been less than 100 in most recent years (Figure 13-8). Returns have recovered slightly from the very low levels between 1989 and 1991 (Lichatowich 1993). These data are presumed to represent the trend of abundance in Salmon Creek. For brood years 1987 to 1996, smolt production averaged 1,400 (Figure 13-8), and egg-to-smolt survival averaged 2 percent (Johnson and Cooper 1993 and 2000). Juvenile steelhead were found in upper Andrews Creek and over-wintering in Crocker Lake (Michael 1989).

13.4.1.4 *Other Species*

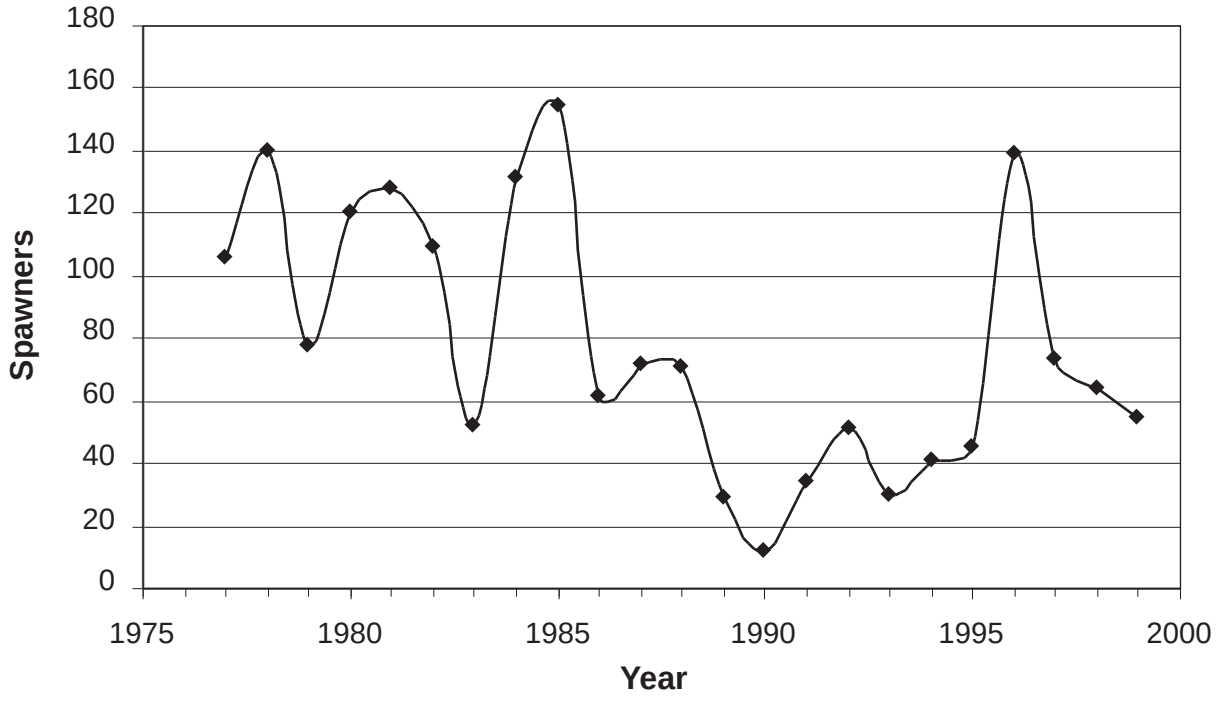
There are records of adult chinook salmon spawning in this drainage, which were probably of hatchery origin (Lichatowich 1993). Fall chum salmon were likely also present historically, but they were probably extirpated in the early 1970's. There have been no fall chum salmon observed passing the Snow Creek weir since 1974, though old spawning ground surveys suggest that they were present historically (McHenry et al. 1996; Williams et al. 1975). Sturgeon have also been oberved in the lower reaches of Salmon Creek.

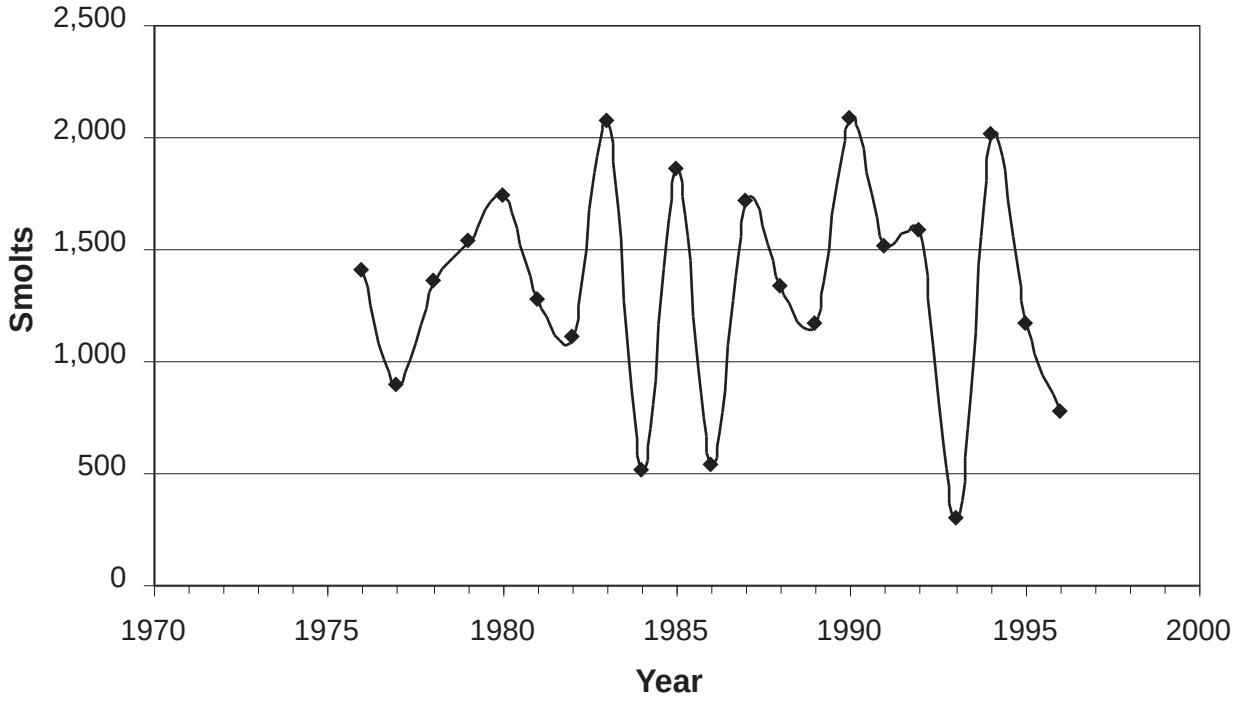
13.4.1.5 *Coastal Cutthroat Trout*

Anadromous coastal cutthroat trout enter the Snow Salmon system in late winter and spring, which is typical of stocks in small drainages. It is common for adults to spawn repeatedly over a period of years, presumably in their natal stream. Some adult cutthroat enter freshwater but don't spawn (Michael 1989). Eggs hatch in six to eight weeks. Juvenile anadromous cutthroat may rear in freshwater up to three years before smolting.

Resident cutthroat populations are distributed into the upper drainage to RM 7.5, and are generally found in small streams up to 1600 foot elevation (SSWAT 1996). Michael (1983) found sympatric anadromous and resident forms in the headwaters of Salmon Creek. The abundance of resident fish has not been estimated. A weir on Andrews Creek prevented migration into the lake and upper drainage for many years. The weir was removed in the 1960's. Brook trout have established a reproducing population, but they only comprise more than 10 percent of the total fish community in upper Andrews Creek, and so don't pose a competitive threat to native species (Michael 1989).

The WDFW Snow Creek research facility has collected an accurate record of the number of anadromous adult cutthroat entering the drainage, and the number of outmigrant smolts. From 1975 to 1985, 25 or fewer adults were trapped in Snow Creek, 80 or fewer in Salmon Creek. Smolt production from Snow Creek has been about 50 each year between 1978 and 1996, and appears to be stable. A trap in upper Andrews Creek captured 217 smolts in 1977. Smolt production in Salmon Creek ranged from seven to 635 (Michael 1989) but there has been a recent declining trend (SSWAT 1996). Michael (1989) estimated over-winter survival of adult cutthroat to be low, perhaps due to low flow.





Source: Johnson and Cooper, 1995.

Figure 13-8
Steelhead Spawning Escapement and Smolt Production in Snow Creek

The status of cutthroat in the Snow Salmon system is believed to be depressed. Their extensive utilization of small tributary streams makes them peculiarly sensitive to the degradation of stream channel and riparian habitat that typifies this system. As the abundance of the anadromous form declines, they may be replaced by the resident form (Michael 1989).

13.4.2 Salmon Creek Habitat Assessment

13.4.2.1 *Channel Condition*

Fish habitat quality was assessed in three reaches of the mainstem: RM 0.2 – 1.3 (Segment 2), RM 1.3 – 1.5 (Segment 3), and RM 2.0 – 3.8 (Segment 5), using the TFW Ambient Monitoring protocol (Bernthal et al. 1999).

Segment 2 is a single-thread channel, characterized by infrequent, shallow pools, and a low volume of LWD. Fines comprise 16 percent of the substrate, which reduces the quality of chum salmon spawning habitat to fair.

Segment 3 is a higher gradient, confined channel, with limited substrate suitable for spawning. Cascades comprise 58 percent of the channel area. LWD is more abundant than in the lower reach, is stable, and creates frequent, small, shallow pools. The substrate is primarily gravel. This reach is likely most suited to use by cutthroat and steelhead (Bernthal et al. 1999).

Segment 5 also has a shortage of stable LWD, and is characterized by infrequent, shallow pools. Gravel comprises 85 percent of the substrate.

The Snow / Salmon Watershed Analysis (SSWAT 1996) assessed habitat quality from aerial photographs and other technical documents, but did not conduct field surveys. Their conclusions with regard to the effects of fluvial processes and interactions with surrounding geomorphology are incorporated into the following summary by Bernthal et al. 1999). Overall, the stream habitat is rated poor, because of inadequate pools, poor to fair LWD recruitment potential, poor bank cover, and high sediment loading from actively eroding banks. The water quality criterion for temperature in class AA streams has been exceeded in Salmon and Houck creeks.

13.4.2.2 *Riparian Zone*

Riparian cover is minimal below Uncas Road in Segment 2, as the adjacent land is developed for agriculture. Along the lower 1.5 miles of the stream 32 percent of the riparian buffer is forested, but 70 percent of the buffer is less than 66 feet wide (Ames et al. 2000). The riparian zone in Segment 3 is forested with a mix of mature conifers and deciduous trees. In Segment 5, the riparian zone is forested with mature deciduous trees, which may continue to contribute LWD to the channel, though it tends to decay faster and be less stable than coniferous LWD (Bernthal et al. 1999).

The Watershed Analysis (SSWAT 1996) assessed LWD recruitment potential based on interpretation of the 66-foot wide riparian zone from aerial photos. The Watershed Analysis rating system was: good - coniferous large wood present in riparian zone; fair - large deciduous trees exist, or there is potential for them to grow; poor - no large standing wood, sparse large deciduous trees and/or sparse young conifers or deciduous stands. In general, the reaches within the National Forest are in better condition. They were harvested intensively in the 1920's, and are now recovering. Second growth harvest has affected Salmon Creek more than Snow Creek. Many reaches in both systems are in fair condition due to stands of red alder that grew after the initial harvest, but alder LWD decays quickly in the stream.

In the Snow / Salmon drainage the gradient profile establishes transport and response reaches with respect to movement of sediment, nutrients, and LWD through the system. Availability of LWD in a transport reach affects channel quality in the response reach below. The narrow, upper canyon reaches limit the ability of the stream to transport large pieces of LWD. With somewhat lower gradient in its mid-reaches, Salmon Creek has less tendency to transport material to the mouth. In Snow Creek a longer deposition zone extends from the Highway 101 crossing to the mouth.

13.4.2.3 *Sub-estuarine Zone*

The delta at the mouth of Salmon Creek and Snow Creek originally covered 70.4 acres. Three dikes now prevent tidal inundation of 25.3 percent of the original delta. Ten roads and causeways cross the delta. These include U.S. Highway 101. A railroad grade reduces tidal circulation, especially to the emergent wetland habitat between Highway 101 and the railroad bed (Ames et al. 2000).

13.4.3 Snow Creek Habitat Assessment

13.4.3.1 *Channel Condition*

Watershed Analysis (SSWAT 1996) provides the most detailed assessment of habitat quality in Snow Creek, but as mentioned above, it was based primarily on interpretation of aerial photographs and other information sources, with very limited field surveys. Nonetheless, it presents a useful description of the processes that have contributed to habitat degradation in the Snow Creek basin.

Canyon reaches in the upper watershed are forced pool/riffle, step pool, and cascades. Hardwood species (e.g. alder) contribute most of the LWD. Canyon walls and hillslopes are still sources of sediment, but the photos indicate that mass wasting has decreased compared with levels indicated in the 1939 photos, which were taken after fires and salvage logging in the 1920's. Coarse sediment in these upper reaches, composed mostly of mudstone and siltstone, is likely to produce fines as it breaks down.

In the lower watershed, as its crosses the alluvial fan, the channel is typed as plane bed, pool riffle, and forced riffle. Pool formation is controlled by LWD presence, whereas in the upper reaches pools are formed by bedrock and boulders. Pools were estimated to comprise 47 percent of the lower channel reaches, and 19 percent of the upper channel.

Diking and straightening of Andrews Creek resulted in entrenchment into alluvial deposits. The artificial channel has probably changed, increased in roughness, slowing velocity and increasing the area of flow (SSWAT 1996). Diversion of Andrews Creek and Crocker Lake into the Snow system probably increased flow by one third.

13.4.3.2 *Riparian Zone*

Agricultural development and timber harvest, combined with re-routing of the stream and channelization, have reduced or eliminated riparian cover along lower Snow Creek. Below RM 3.0 only 42 percent of the riparian zone is forested, and 76 percent of the existing forested buffer is less than 66 feet wide (Ames et al. 2000). Trees in the buffer are all less than immature (i.e. less than 20 inches dbh). The riparian zone in the upstream transport reaches of Snow Creek is in relatively good condition, with dense, mature conifers, except near the confluence of Rixon Creek where the buffer narrows and is sparsely forested with mature alder.

13.4.3.3 *Sub-estuarine Zone*

The sub-estuarine zone of Snow Creek is shared with Salmon Creek, which has been described above.

13.4.4 Limiting Factors for Salmon Creek Summer Chum Salmon

There are few deep holding pools below RM 3.8, and minimal bank vegetation or cover in Segment 2 (below Uncas Road). These factors may expose migrating adults to predation. Segment 2, the primary spawning area for summer chum salmon, has elevated fine sediment levels which may reduce the survival of incubating eggs. Sediment has moderate impact on spawning and incubation stages. The confined channel increases potential for sediment accumulation, redd scour. Sediment sampling found 15 percent fines by volume (PNTPC et al. 1999)

Low flow during the migration and spawning season, and high flow during the incubation period have reduced the reproductive success of summer chum salmon. Reduced channel complexity, due to lack of LWD, loss of side channels, and channel instability have had a high impact on spawning and incubation survival. Timber harvest and agricultural development have reduced or eliminated riparian buffers, LWD, side channels, and adjacent wetlands in the reaches now or formerly utilized by summer chum salmon. (PNTPC et al. 1999). In Segments 2, 3, and 5, LWD volume ranged from 0.03 to 0.19 key pieces per channel width, compared to fully functional volume of at least 0.30 pieces per channel width. The low potential for LWD recruitment, particularly of coniferous wood, suggests that habitat will continue to degrade until a functional riparian zone is re-established – a process requiring 50 to 100 years if reforestation were begun immediately (Bernthal et al. 1999)

Degradation of the sub-estuary has impacted the survival of post-emergent summer chum salmon (Ames et al. 2000).

13.4.5 Limiting Factors for Snow Creek Summer Chum Salmon

Channel instability, high peak flows, loss of LWD, and high sediment loading are the principal factors that limit production of summer chum salmon in Snow Creek.

Because riparian buffer zones were cleared, stable log jams are scarce, side channels and associated wet areas were eliminated, and channel complexity is much reduced. This has had moderate to high impact on spawning habitat quality and incubation survival. LWD volume was estimated to be 0.07 pieces/m (Ames et al. 2000), whereas functional LWD volume should range from 0.15 to 0.30 key pieces per bankful width. Pools comprise 47 percent of the channel area, and pool frequency is 5.7 channel widths.

Channel confinement and bank hardening has resulted in increased winter flow, which causes scouring of the stream bed. High sediment loading, combined with processes that aggrade and scour the channel, has reduced spawning habitat quality and egg survival. Fines comprise 18 percent of the substrate in the reach used by summer chum salmon. Aggradation also worsens the effects of low summer stream flow, and may affect access to spawning areas. Channel re-routing in the lower reach and loss of channel complexity has reduced the rate at which sediment is transported through the system. The diversion of Andrews Creek into the Snow drainage may also increase high winter flows (Ames et al. 2000).

The riparian zone adjacent to the lower reach is in poor condition. Only 42 percent of the narrow riparian buffer below RM 3.0 is forested. Trees are immature, and less than 20 inches in diameter. The lack of LWD in the stream has reduced channel complexity, so spawning and incubation habitat has been highly impacted. Summer water temperature has been shown to exceed the criteria of 16.3 ^{o}C for class AA streams. From 1977 – 1990 mean monthly stream temperature was 19.5 ^{o}C in June, 20.5 ^{o}C in July, 20 ^{o}C

in August, and 18.3 ^{o}C in September (Lichatowich 1993a). Low flow, lack of riparian cover, and sedimentation have contributed to these high stream temperatures. Diversion of the outlet of Crocker Lake into the drainage may also elevate stream temperature.

Estuarine habitat loss and degradation by roads and causeways has had high impact on rearing and migratory life stages.

13.4.6 Salmon-Snow Watershed Analysis

The Watershed Analysis (SSWAT 1996) noted the importance of wetlands in the Salmon-Snow drainages in buffering precipitation runoff and maintaining base period flow. The underlying geology has promoted wetland formation, but these areas have been altered by grazing, road building, and timber harvest, so they no longer function at full capacity.

The declining status of coho salmon is attributed to habitat degradation, in particular those factors that exacerbate low summer flows, limit LWD recruitment, and contribute to sediment loading. These effects are presumed to be decreasing as the riparian forest regenerates, but grazing continues to impact the riparian zone in the lower reaches. Bare and eroding banks are common (Nelson et al. 1992).

The high road density in the upper Snow Creek watershed contributes to sediment loading of the stream channel. Twelve areas of mass wasting were identified on aerial photographs. The largest flood in the 14-year period of streamflow record occurred in January of 1983. Other very high flows were recorded in December 1982, and January 1986 (Jones and Stokes 1991 as seen in SSWAT 1996).

13.4.7 Restoration Activities

Completed restoration projects in the Salmon-Snow sub-basin are summarized in Table 13-9.

Table 13-9. Summary of Completed Restoration Projects in the Salmon-Snow Sub-basin

Stream	Date	Restoration Type	Description
Salmon Creek	9/30/1997	Salmon Habitat Restoration	Larrance: Fish stream imp.: Salmon Crk
Salmon Creek	12/30/1997	Riparian Fencing	Flood proof fence - Salmon Crk
Salmon Creek	3/30/1995	Riparian Fencing	Bowman fence
Salmon Creek	12/30/1997	Riparian Planting	Streambank seed/mulch Salmon Crk
Snow Creek	1997	Fencing	Installed fencing along 2,000 ft of one bank and 40 ft of other bank to keep livestock out of the stream between RM 1.0-1.4
Snow Creek	12/30/1997	Riparian Fencing	Andrews fencing
Snow Creek	12/30/1997	Riparian Fencing	G. Brown fencing
Snow Creek	12/30/1997	Riparian Fencing	Andrews Fence - Snow Crk.
Snow Creek	12/30/1997	Riparian Fencing	Brown Fence -Snow Creek
Snow Creek	9/30/1995	Salmon Habitat Restoration	Schmidt stream restoration proj.
Snow Creek	9/30/1995	Salmon Habitat Restoration	1995 stream restoration project, lowered channel grade to match natural conditions
Snow Creek	9/30/1995	Salmon Habitat Restoration	Zerr stream restoration proj.
Snow Creek	8/30/1997	Salmon Habitat Restoration	Snow Crk: Fish passage barrier removal
Snow Creek	3/31/1998	Riparian Planting	Rip. plant, Andrews/Brown, Snow Crk
Andrews Creek	1995	Geomorphology/Revegetation	Recreated a single channel, revegetation of ripairan zone, fenced to keep livestock out of the stream from RM 0.84-1.29

Table 13-9. Summary of Completed Restoration Projects in the Salmon-Snow Sub-basin (continued)

Stream	Date	Restoration Type	Description
Andrews Creek	12/30/1994	Riparian Fencing	Boulton/WSDOT fencing
Andrews Creek	11/30/1995	Riparian Fencing	Phinizy fence
Andrews Creek	12/30/1995	Riparian Fencing	Gastman stream fencing
Andrews Creek	12/30/1994	Salmon Habitat Restoration	WSDOT stream restoration project
Andrews Creek	6/30/1995	Salmon Habitat Restoration	Phinizy stream restoration project
Andrews Creek	12/30/1995	Salmon Habitat Restoration	Gastman stream restoration project
Andrews Creek	12/30/1995	Riparian Planting	WSDOT planting
Andrews Creek	12/30/1995	Riparian Planting	Phinizy riparian planting along 500 ft of channel
Andrews Creek	4/30/1996	Riparian Planting	Gastman riparian planting
Andrews Creek	3/31/1998	Riparian Planting	Rip. plant, Gastman/WSDOT, Andrews Crk

The following three restoration projects have been proposed for construction during the summer of 2000 or later in the Salmon-Snow Sub-basin.

- Reconfigure a reach of Salmon Creek between RM 0.0-0.6 by adding LWD, fencing and native riparian vegetation. This project is sponsored by JCCD.

- Supplement Summer chum salmon between RM 0.0-0.5 of Salmon Creek. This is the eighth year of an ongoing project funded by Wild Olympic Salmon (WOS).

- Supplement coho salmon in Snow Creek. This project was begun in 1999 and is funded by WDFW.

13.5 INSTREAM FLOW

Hiss (1993) presents optimum flows for Salmon Creek and Snow Creek. Species and lifestages considered were chum salmon, coho salmon and steelhead spawning, and coho salmon and steelhead rearing, as appropriate (see Table 6-3). Optimal flows for Salmon Creek range from a low of 9 cfs for steelhead juvenile rearing to a high of 43 cfs for chinook salmon and chum salmon spawning. Optimum flows for Snow Creek range from a low of 9 cfs for steelhead juvenile rearing to a high of 66 cfs for chum salmon spawning. Snow Creek has been under long-term study by WDFW. Population density information, adult upstream migration and juvenile outmigration information have been collected and analyzed.

13.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS

13.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity

At the time of this writing, the only data available to characterize or predict future changes in land use were the population projections presented in Chapter 1. For several types of land use (e.g. logging and agriculture), the lack of specific information regarding anticipated future changes makes it impossible to predict related impacts to groundwater and surface-water quantities. General discussion of the relationships between these particular land uses, streamflow and groundwater recharge is included in Chapter 4. However, it should be noted that the impacts of such land uses may be highly dependent on particular site characteristics.

The population projections and zoning patterns discussed above, however, can be used to qualitatively predict changes in patterns of residential and associated commercial land use. Increased population requires increased paved surfaces for homes, driveways, roads, and commercial infrastructure. In the Salmon-Snow sub-basin, most of the projected growth is likely to occur in rural residential areas, and thus dense areas of paved surfaces are not expected. As indicated in Chapter 4, little direct data are available regarding the effects of paving on groundwater recharge at typical rural residential densities. While the effects of increased paving in rural residential areas are not expected to be substantial, some reduction in recharge may be associated with conversion of forested lands to meadows and lawns. The effect of population increase on groundwater and surface water withdrawals is presented in Section 13.6.3.

13.6.2 Sub-basin Population Growth

In 1996, the Salmon-Snow sub-basin had 1,085 residents (Jefferson County 2000). Salmon-Snow sub-basin population growth over the next 20 years is estimated at 385 residents (Jefferson County 1998). Based on existing zoning (refer to Exhibit 1), the population growth will most likely occur along the lower 3 miles of the Snow Creek corridor and along the southeast Discovery Bay shoreline.

13.6.3 Potential Impacts of Growth on Water Demand

Population in the Salmon-Snow sub-basin is expected to increase by 35 percent between 1996 and 2016. Assuming that an average residence contains 2.2 people and uses 250 gpd, the projected increase of 385 people will cause an increased water demand of approximately 49 af/yr. Groundwater is currently the principal source of residential supply for most of the sub-basin, and is predominantly withdrawn by exempt wells with a few small public water systems. Additional demand will likely be satisfied by similar sources. If additional demand is met with the groundwater resource, estimated current groundwater withdrawals (158 af/yr for residential, commercial and agricultural purposes) would increase by about 31 percent. The increased demand also represents about 0.5 percent of estimated groundwater recharge, with current groundwater withdrawals estimated at 1.7 percent. However, as discussed in Chapter 4, comparison of groundwater pumping with recharge cannot be reliably used as a direct indicator of groundwater availability.

Given the rural nature of the sub-basin, residential reliance on septic systems dictates that the consumptive portion of residential use is significantly less than the total residential groundwater withdrawal. Assuming that 87 percent of residential withdrawals are returned to the ground via septic infiltration (Solly et al. 1993), the actual increase in groundwater consumption would be on the order of 6 af/yr.

13.6.4 Potential Impacts of Growth and Land-Use on Habitat

The degraded state of much of the riparian zone of Salmon Creek and Snow Creek, and channel modification related to residential and agricultural development in the lower valleys, exacerbate high winter stream flow, erosion, and sediment loading, and severely limit the recruitment of LWD into the channel. LWD is essential for providing the complex habitat needed by rearing salmonids (coho salmon, steelhead, and cutthroat), and mitigating the energy of high winter flows.

13.6.5 Conservation Options for the Salmon-Snow Sub-basin

Water conservation options that may be applicable to water users in the Salmon-Snow Sub-basin are summarized below.

- Tiered Water Rate Structures

- Modification of Landscape Irrigation Practices
- Water Conservation in Water Supply Systems and Individual Homes
- Educational programs
- Water Conservancy Boards To Facilitate Water Rights Transfers

13.7 DATA SYNTHESIS AND INTEGRATION

Groundwater use (25 af/y) or claims (up to 44 af/y) do not comprise a substantial proportion of the estimated total recharge of 9460 af/y. Potential hydraulic connectivity is moderate in the Snow Creek mainstem, and lower Salmon Creek, and low in upper Salmon Creek and smaller tributary streams in the sub-basin. Growth projections for the sub-basin, which suggest that the population will increase by 35 percent by 2016, are unlikely to significantly affect base flow by withdrawing groundwater. However, surface water diversions, which are primarily used for irrigation, can affect base flow, though consumptive use is unquantified. Surface water planning should take into account the objectives of fisheries management in the sub-basin, which will focus primarily on the needs of summer chum salmon and coho salmon.

Degraded stream channels and the associated riparian zone, and the sub-estuary at the head of Discovery Bay, are the primary factors limiting salmonid productivity in the Snow – Salmon sub-basin. Low base flow is also cited as a limiting factor, but analysis of groundwater and surface water volumes in this assessment suggest that current development does not significantly influence streamflow. Low base flows are a more natural consequence of the location of the sub-basin, in the rain shadow of the Olympic Mountains.

Water quality problems include exceedence of state standards for temperature, dissolved oxygen, sediment load, and fecal coliforms, and are directly related to land-use practices.

13.8 DATA QUALITY, GAPS AND LIMITATIONS

In addition to the general data gaps identified for the entire WRIA, the following specific data gaps have been identified for this sub-basin:

13.8.1 Water Quality

- Assessment of forestry activities in the upper portions of the watershed to determine potential impacts to streams that are susceptible to erosion.

- Update the 1993 inventory agricultural activities by the River Basin Study Team, particularly in the Snow Creek and Andrews Creek corridors, and identify location where these activities could be impacting water quality.

13.8.2 Water Quantity

Water quantity data gaps identified for the entire WRIA apply to the Salmon-Snow sub-basin. The following data gaps are specific to this sub-basin:

- Assess unpublished Snow Creek stream flow data collected by WDFW at the WDFW research station.

13.8.3 Habitat

- Quantify the stream flow volume needed to support summer chum salmon spawning in the lower reaches of Snow Creek and Salmon Creek.
- Quantify the effects of high winter peak flows on sediment transport and scour in spawning areas.
- Measure early marine survival of juvenile summer chum salmon in the sub-estuary.
- Stream and riparian habitat assessment in Contractors Creek.

13.8.4 Instream Flow

Due to lack of previous instream flow work, Snow Creek and Salmon Creek should be considered for collection of additional instream data, either using the toe-width method or the IFIM method. The WDFW has noted that there may be sufficient fish data to determine instream flows for these streams without doing an IFIM study.

14. WEST SEQUIM BAY SUB-BASIN

14.1 BASIN DESCRIPTION

The West Sequim Bay sub-basin is located in the northern portion of WRIA 17 and drains to Sequim Bay through numerous small streams (Figure 14-1).

14.1.1 Surface Water Features

Four significant surface water drainages discharge into Sequim Bay from the West Sequim Bay sub-basin. They are Johnson Creek, Dean Creek, Jimmycomelately Creek and Chicken Coop Creek. A series of smaller unnamed creeks between Johnson and Dean Creek also provide runoff to the southern shore of Sequim Bay.

Jimmycomelately Creek is the primary freshwater feature in this sub-basin and has a watershed that covers approximately 19 square miles. In the early 1900's the lower portion of this stream was moved and confined by dredge spoils and isolated from the estuary. Numerous small streams drain the remainder of this sub-basin including Johnson, Dean, and Chicken Coop creeks. Most of these creeks have low or intermittent flows during summer months. Bell Creek drains to extreme northern portion of Sequim Bay; however, it was considered outside the WRIA 17 boundary. Surface water features for the West Sequim Bay sub-basin are summarized in Table 14-1.

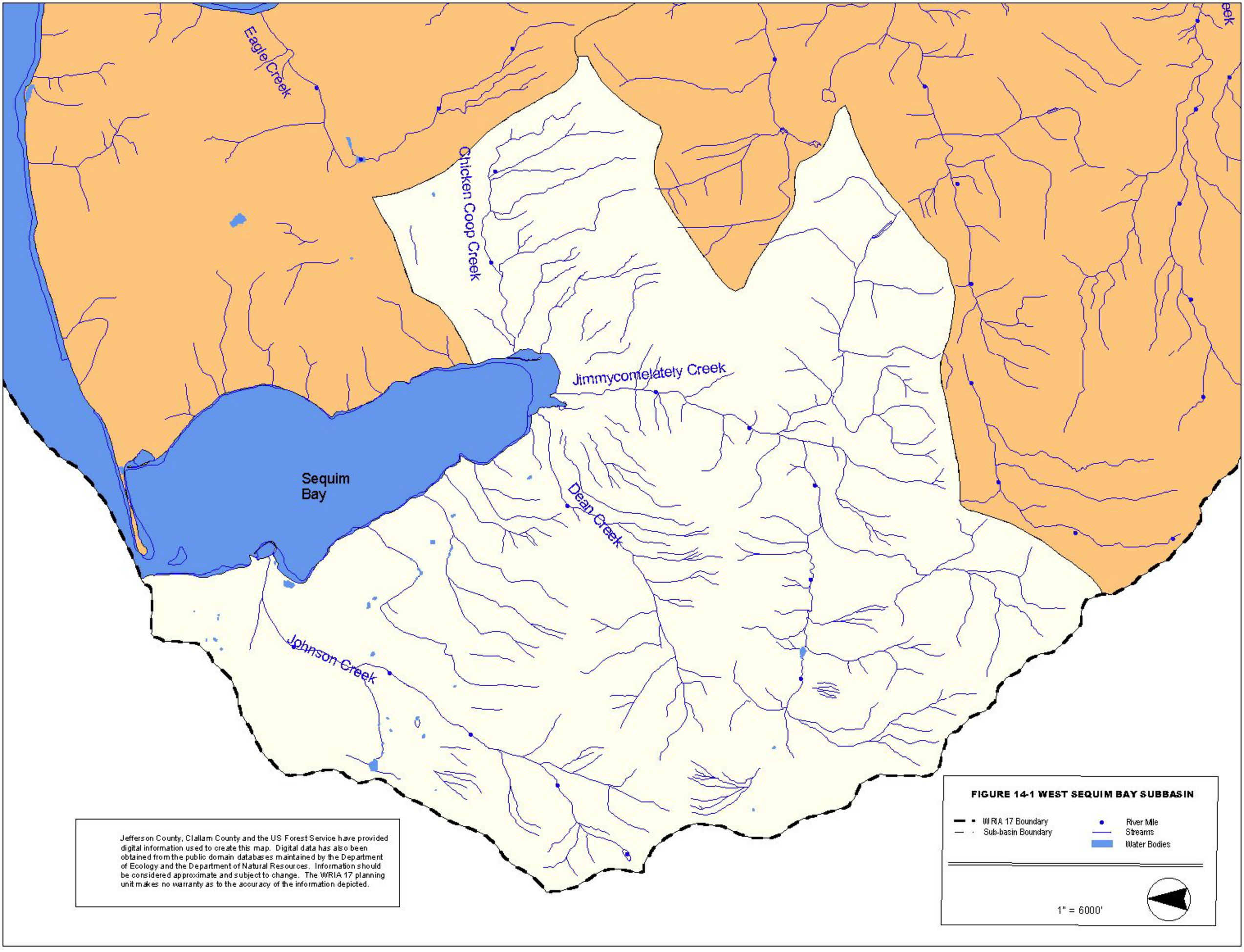
Table 14-1. Fresh Water Features in the West Sequim Sub-basin

Main Water Feature	Ecology Class	DNR Class
Jimmycomelately Creek	Class AA	2
Johnson Creek	Class AA	2
Chicken Coop Creek	Class AA	2
Dean Creek	Class AA	2

Source: Williams et al. (1975)

Johnson Creek begins in two branches, with the west branch starting out at elevation 240 ft (draining an unnamed pond or lake) and the east branch starting at an elevation of 660 ft. Measured flows on the creek range from less than 0.1 cfs to about 10 cfs. Summer flows are generally in the range of 0.1 to 1.5 cfs. Streamflow data on Johnson Creek was obtained for the DQ Plan and then for studies reviewing the impact of lining or piping irrigation canals in the Sequim-Dungeness area. One of the canals that diverts water from the Dungeness River (Highland Canal) spills tailwater into Johnson Creek which is then used for irrigation downstream of the spill. The USGS (Thomas et al. 1999) and the Sequim-Dungeness Valley Agricultural Water Users Association (Jeldness 1996 –1998) have collected periodic data on Johnson Creek from about 1996 to the present. Some of that data is also summarized in the Dungeness River Agricultural Water Users Association Comprehensive Water Conservation Plan (Montgomery Water Group 1999).

Headwaters for Dean Creek begin at an elevation of 690 ft and are approximately 4 miles from the discharge point in Sequim Bay.


Eagle Creek
Chicken Coop Creek
Jimmycomelately Creek
Sequim Bay
Dean Creek
Johnson Creek
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
FIGURE 14-1 WEST SEQUIM BAY SUBBASIN
WRIA 17 Boundary
Sub-basin Boundary
River Mile
Streams
Water Bodies
1" = 6000'

Jimmycomelately Creek is the longest of the four creeks at almost 9 miles long and has headwaters located at an approximate elevation of 1,080 ft. It drains a basin of 19 square miles, most of which (above RM 2.0) is in the Olympic National Forest. There are 20 miles of stream channel, which flow north from headwaters at 3,800 feet to the mouth at the south end of Sequim Bay. Below RM 1.0 the land adjacent to the stream is developed for residences and small farms. In the early 1900's the lower portion of this stream was moved and confined by dredge spoils, isolating it from the sub-estuary.

Chicken Coop Creek starts at an elevation 420 ft and empties into Sequim Bay 3 miles downstream.

14.1.2 Groundwater Features

Hydrogeologic characterization for the West Sequim Bay sub-basin includes mapping of surficial geology and a USGS study that describes regional aquifers, aquitards, groundwater flow directions and presents two hydrogeologic cross-sections in the area (Thomas et al. 1999). The sub-basin is characterized by extensive areas covered with bedrock, till covered areas on either side of Sequim Bay, and a moderate sized recessional outwash delta at the head of Sequim Bay. Beneath the till, the principal aquifer system is relatively stratified and has been characterized in a recent USGS study of the Sequim-Dungeness area (Thomas et al, 1999). The study identified six hydrostratigraphic units overlying bedrock: the "shallow aquifer", the "upper confining bed", the "middle aquifer", the "lower confining bed", the "lower aquifer", and undifferentiated unconsolidated deposits. The shallow aquifer is primarily composed of Vashon glacial sediments. Both the middle and deep aquifer (where present) are composed of pre-Vashon materials, and extend beneath Sequim Bay into the Miller sub-basin. Sedimentary textures can vary greatly within the aquifer units identified. The confining beds are generally fine grained, but may contain discontinuous lenses of water bearing sand and gravel.

Surficial geology in the West Sequim Bay area is shown on Exhibit 17. West of the bay, the principal aquifer system is relatively thin just north of the large bedrock body, and only the shallow aquifer is noted to occur. Further to the north, depth to bedrock increases rapidly with distance away from the isolated bedrock exposures. A deltaic recessional outwash deposit at the head of Sequim Bay may function as a local aquifer, however its water yielding characteristics are not documented. A portion of the Miller Peninsula occurs within the sub-basin, and it is noted that the hydrogeologic units identified in the USGS study were more difficult to discern beneath the peninsula.

14.1.3 Land Use

The majority of the land use in the West Sequim sub-basin is within commercial forestry, (66 percent of total). The U.S. Forest Service manages most of the land in this sub-basin. A small number of residential and small farms exist in the lower portions of the sub-basin. Residential lands comprise approximately 30 percent of the sub-basin with the primary residential land use of one dwelling unit per five acres. The City of Sequim and the Sequim UGA comprise approximately 3 percent of this sub-basin. Existing land use in this sub-basin is shown in Table 14-2.

Table 14-2. West Sequim Bay Sub-basin Land Use

Description	No. of Parcels	Acres	% of Total
City of Sequim	NA	580	2.4%
Sequim UGA	NA	168	0.7%
Rural Residential (1:20)	7	2,018	8.5%
Rural Residential (1:5)	NA	2,723	11.4%

Table 14-2. West Sequim Bay Sub-basin Land Use (continued)

Description	No. of Parcels	Acres	% of Total
Rural Center	NA	414	1.7%
Rural Residential (1:20)	NA	1,957	8.2%
Rural Commercial	NA	18	0.1%
Rural Suburban	NA	77	0.3%
Public	NA	82	0.3%
Tribal	NA	28	0.1%
Commercial Forest	4	15,765	66.2%
Totals	**11**	**23,830**	**100.0%**

N/A = Not Available. Parcel data is for Jefferson County only.
Source: Clallam County GIS (2000).

14.2 WATER QUALITY

14.2.1 Surface Water Quality

No water quality data was available for freshwater features in the West Sequim Sub-basin. Jimmycomelately and Johnson Creek were generally assumed to have good water quality (Ecology 1998b).

14.2.2 Marine Water Quality

Sequim Bay has documented water quality problems, however little raw data was available to support the conclusions summarized below. Ecology has indicated that the Bay is becoming more anoxic (Ecology 1998b). The DOH closed an area in the northern portion of the bay to shellfish harvesting but the remainder of the Bay is conditionally approved (PSEP 1992). The DOH has continuously sampled water quality at 20 station in Sequim Bay since 1992 (DOH 1999b), and results indicate that FC is increasing at ten of the stations (Stations 2, 4, 6, 7, 8, 12, 16, 17, 19, and 25), remaining the same at seven stations (1, 3, 10, 11, 13, 22, and 26), and decreasing at the remaining three stations. FC concentrations were below the allowable limits for shellfish harvesting, even in areas that contributed non-point source pollution such as the mouth of Jimmycomelately Creek. However, shellfish harvesting is still prohibited or conditionally approved in the bay because of the proximity to point sources (DOH 1999b).

14.2.3 Inventory of Potential Surface Water Contaminant Sources

14.2.3.1 *Point Sources*

Ten point sources of pollution have been identified based on NPDES permits. The Sequim Bay Sewer Treatment Facility (STF) has been a significant source of untreated sewage to Sequim Bay (DOH 1999b). Shellfish harvesting is conditionally approved in this location due to the outfall of the STF. Point sources, each with an individual NPDES permit, are summarized below from Ecology (1999a):

- Battelle Marine Sciences Lab
- Sequim Bay State Park Sewer Treatment Plant
- Dunlap Towing and Blyn Log Yard
- Clallam County PW and Blyn Pit
- Washington State Dept. of Transportation Pit Q83
- Jefferson County PW Blyn Pit
- ATandT Blyn
- USWCOM Blyn Td2 Radio Building

- Elwick Dam
- Lucinda Lake Dam

It is noted that NPDES point source locations have been provided by Ecology and in some cases may depict facility names and locations that may not be entirely representative of existing conditions. The Ecology database does also not distinguish between stormwater and/or wastewater permits. No specific monitoring data or compliance problems were available for these specific point sources.

14.2.3.2 *Non-Point Sources*

Forestry and agricultural operations such as livestock rearing and hay harvesting have been identified as the main sources of non-point pollution in this sub-basin. Urban and residential use is sparse. Several irrigation ditches located in the Bell and Johnson creeks basins contributed elevated FC loads to these streams and it was estimated that Bell Creek contributed approximately 90 percent of the FC load entering Sequim Bay (DOH 1999b). A study done by Ecology indicated that Bell Creek was the single largest source of bacteria to Sequim Bay (Ecology 1998b).

14.2.4 Summary of Trends and Compliance Problems

Ecology has listed Chicken Coop and Johnson creeks on the 303(d) list for exceeding FC criteria in 1996 and 1998 (Ecology 1998a).

Ecology has also placed Sequim Bay on the 303(d) list for exceeding pH, DO, and FC criteria in 1996 and exceeding pH and DO in 1998. Sequim Bay sediments have also been listed for exceeding polycyclic aromatic hydrocarbon (PAH) Apparent Effects Thresholds (AETs). Shellfish harvesting has been prohibited for the last decade near the entrance to Sequim Bay due to non-point pollution in Bell Creek, and the remainder of the bay is Conditionally Approved due to the Sequim STP (DOH 1999b).

14.2.5 Groundwater Quality

Chloride concentrations in the West Sequim Bay Sub-Basin are mapped on Exhibit 4. The majority of wells are located along the coast. Three of these coastal wells exhibit chloride concentrations exceeding 250 mg/l, and one well shows a concentration between 100 and 250 mg/l. No clustering is noted among high chloride wells, and coastal wells with background concentrations (<50 mg/l) are more common. Nevertheless, the isolated pockets of elevated chloride suggest localized susceptibility to intrusion.

Nitrate concentrations are available from only six wells in the West Sequim Bay Sub-Basin, and only one of which exceeds the natural background range (Exhibit 5). No incidents of anthropogenic groundwater contamination have been diagnosed in the West Sequim Bay Sub-Basin.

14.3 WATER QUANTITY

14.3.1 Groundwater Quantity

Groundwater recharge estimated for the West Sequim Bay sub-basin is approximately 6,500 af/yr, and averages 3.2 in/yr over the entire area. This relatively low value of recharge is due to the extensive presence of bedrock, which occupies about 75 percent of the sub-basin. Exhibit 6 shows that recharge estimated for the non-bedrock areas of the sub-basin straddles a contact between precipitation “bands”, showing different values on either side of the band. The majority of predicted recharge in till covered areas ranges from 5-10 in/yr, and values or 10-20 in/yr are noted in outwash areas. Precipitation, which averages 28 in/yr over the sub-basin, is the limiting factor for recharge. Throughout the sub-basin,

precipitation minus plant evapotranspiration does not exceed the transmitting capacity of the till. Rejected recharge (runoff) is predicted to be largely absent from till-covered areas due to the relatively low rainfall.

14.3.2 Surface Water Quantity

No surface water quantity information was available for this sub-basin other than that data reported in Section 14.1.2.

14.3.3 Estimate of Water Use and Allocation

14.3.3.1 *Groundwater Use and Allocation*

Exhibit 11 shows the spatial distribution of groundwater use in the West Sequim Bay sub-basin. The total groundwater withdrawal, assuming a domestic use of 250 gpd, is 304 af/yr. Approximately 25 percent of this total use is estimated from water rights and claims for irrigation purposes, and is qualified as being "lower accuracy" data. The remaining 75 percent (227 af/yr) is based on various sources for domestic and commercial uses, and is believed to be relatively high quality data. The groundwater withdrawal estimated for single family domestic wells (135 af/yr) is based on a count of well logs from the Clallam County database, and likely underestimates the full single domestic withdrawal. While total domestic use is likely higher than estimated due to the presence of unreported domestic wells in the sub-basin, the *consumptive* portion of domestic groundwater use is likely to be much lower because all households in the sub-basin use septic systems.

In the West Sequim Bay sub-basin, 23 groundwater rights have been issued for a total of 368 af/yr. The spatial distribution of groundwater rights is presented in Exhibit 8. Figure 14-2, a pie chart of groundwater rights by use, shows that approximately 94 percent of the total allocation is for domestic multiple or single use and 6 percent is for irrigation.

There are 481 well logs for the West Sequim Bay sub-basin contained in the Clallam County well database, translating to a potential exempt allocation of 2,694 af/yr. More unregistered wells are likely to exist, however only a small portion of this exempt allocation is likely to be actually put to use.

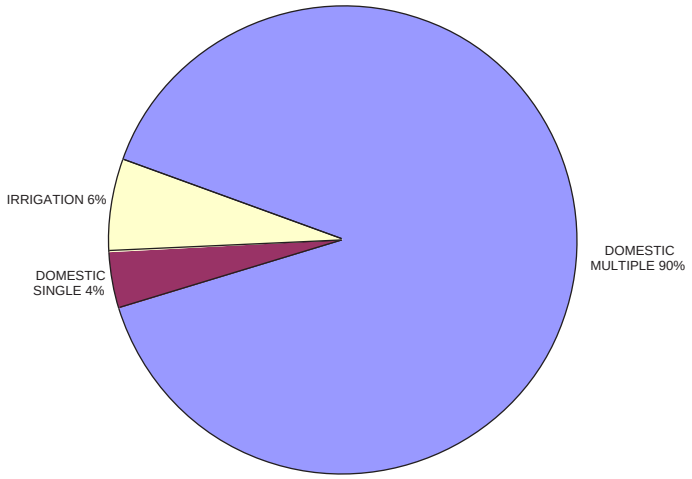
There are 107 groundwater claims in the sub-basin. Table 4-3 lists claims by use, and shows that 22 of these claims list irrigation as a principal use. Typically, only a portion of claims listing irrigation as a purpose-of-use list numbers of irrigated acres. In the West Sequim Bay sub-basin, water use associated with the reported numbers of irrigated acres amounts to 60 af/yr. If each claim is also assumed to include a domestic use, total claimed groundwater can be estimated at about 167 af/yr. The portion of these claims that have been actually put to use, and would qualify for a water right, is unknown. A map of the distribution of groundwater claims is presented on Exhibit 9.

There are no water right applications in the West Sequim Bay sub-basin.

14.3.3.2 *Surface Water Use and Allocation*

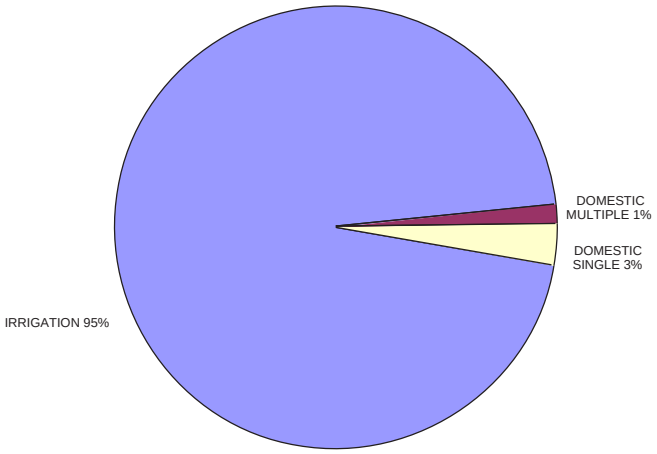
Table 14-3 shows the relative distribution of consumptive use water rights in the West Sequim Bay sub-basin. The largest use of water is for irrigation, comprising 56 percent of the total instantaneous quantity and 95 percent of the total annual quantity. The next largest use is for domestic multiple uses followed by domestic single and for stock. Figure 14-2 presents pie charts of the relative distribution of water rights. The total consumptive use rights are 6.8 cfs and 809 af/yr annual quantity. Claims data indicate that 0.7 cfs are claimed with an annual quantity estimated at 70 af/yr. The claims data is not reflected on the pie

GROUNDWATER RIGHTS (QA) BY USE



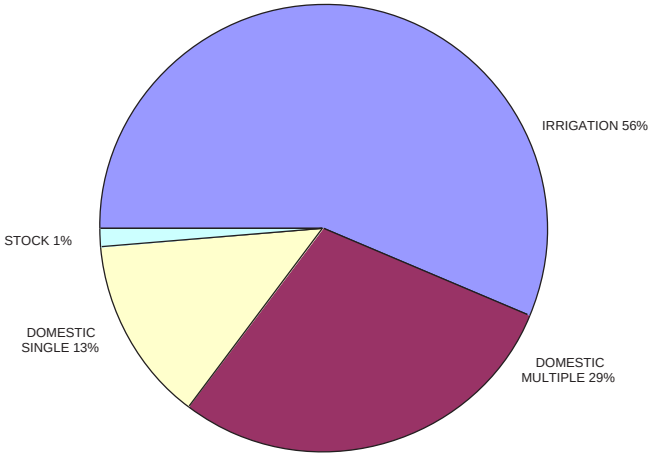
Note: total allocation = 368 af/yr, accounted by use = 271 af/yr, domestic exempt wells = 2694 af/yr

SURFACE WATER RIGHTS (QA) BY USE



Note: total allocation = 809 af/yr, accounted by purpose 786 af/yr, no additional non-consumptive rights as Qa

SURFACE WATER RIGHTS (QI) BY USE



Note: total allocation = 6.8 cfs, accounted by purpose = 8.1 cfs, no additional non-consumptive rights as Qi

Source: Ecology WRATs database

Figure 14-2
West Sequim Sub-Basin Groundwater and Surface Water Rights and Use, Consumptive Use Only

Table 14-3. Analysis of Surface Water Allocation in West Sequim Bay Sub-Basin

Purpose	Percent Qi	Percent Qa
DM	29%	1%
DS	13%	3%
FR	0%	0%
IR	56%	95%
ST	1%	0%

Explanation of Purpose Codes:

CI	Commercial and Industrial Manufacturing	FS	Fish Propagation
DM	Domestic Multiple	IR	Irrigation
DS	Domestic Single	MI	Mining
MU	Municipal	ST	Stock Watering
FR	Fire Protection		

charts. The spatial distribution of surface water rights (Qa), claims (Qi), and claims (Qa) are shown in Exhibits 13, 14, and 15, respectively.

14.3.4 Hydraulic Continuity Potential

The major streams in the West Sequim Bay sub-basin are all assigned a "low" RHCP ranking where they flow across bedrock or till. Near West Sequim Bay, many of the streams flow within channels of alluvial or recessional outwash deposits. Channels over till are assigned a "medium" RHCP ranking. At the head of the bay, the recessional outwash sediments tend to thicken into a deltaic deposit. Hydrogeologic characterization was not available to determine if that deltaic deposit functions locally as a principal aquifer, and a "medium" ranking was maintained across the deltaic sediments. If the delta serves as a local principal aquifer, a "high" ranking should be assigned. Chicken Coop Creek may cut into advance outwash sediments at its mouth, and was assigned a "high" RHCP in this location.

14.4 HABITAT

Information on salmonid stock status and habitat quality in the West Sequim Sub-basin is only available for the Jimmycomelately Creek drainage.

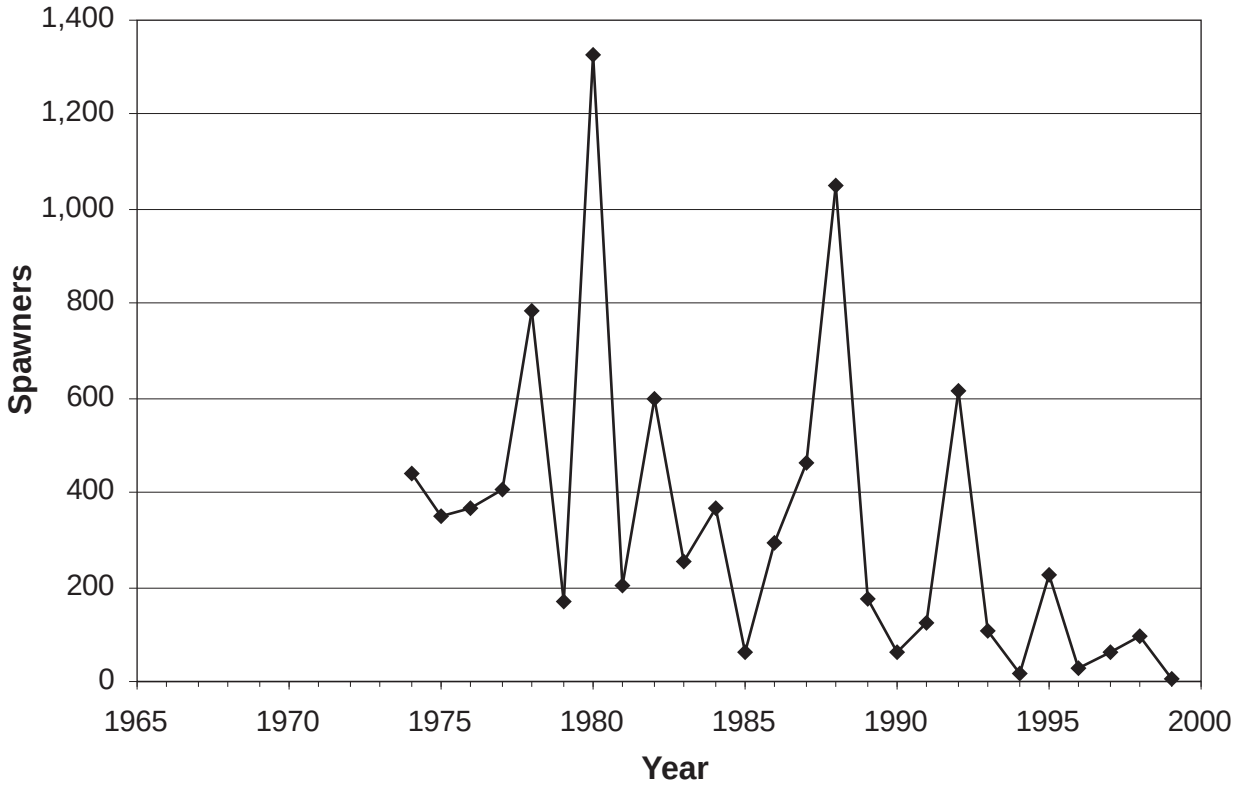
14.4.1 Salmonid Distribution And Stock Assessment

Summer chum salmon and coho salmon inhabit Jimmycomelately Creek, and their distribution and status are known from annual spawning escapement surveys. Winter steelhead and resident cutthroat trout are also present but their distribution is not described and their recent abundance is unknown.

14.4.1.1 *Summer Chum Salmon*

Summer chum salmon currently spawn up to RM 1.5. Historically their distribution extended up to RM 1.9, where an impassable falls blocks anadromous access (Ames et al. 2000).

Genetic analysis of summer chum salmon collected from Jimmycomelately Creek show them to be significantly different from the adjacent stock in Snow Creek and Salmon Creek. They are a native stock, and no hatchery supplementation has occurred. Spawning escapement ranged from several hundred to 1,000 in the 1989's, but declined in the 1990's to less than 100 (Figure 14-3). Because of this short-term,



Source: Ames et al., 2000.

Figure 14-3
Summer Chum Spawning Escapement to Jimmycomelately Creek, 1974-1999

severe decline their status is judged to be critical. The effective population size for the period between 1995 – 1995 was 74, so their risk of extinction is high (Ames et al. 2000).

14.4.1.2 *Coho Salmon*

Coho salmon spawning surveys in the lower 1.5 miles of Jimmycomelately Creek have observed between 20 and 40 redds since 1990 (Figure 14-4). There have been numerous plants of non-native, hatchery-reared smolts into the drainage, so the stock is of mixed native / introduced origin. The aggregate Eastern Strait coho salmon management unit was judged to be depressed in the SASSI document (WDF et al. 1993), but more recent evaluation has concluded that this stocks is at the critical level.

14.4.2 Jimmycomelately Creek Habitat Assessment

Watershed Analysis is currently in preparation, but little information is currently available that assesses the impacts of roading and timber harvest in upper basin on stream habitat. Logging activities and road failures have contributed sediment to stream, but timber harvest has occurred at a lower rate than in other adjacent drainages (McHenry et al. 1996).

14.4.2.1 *Channel Condition*

There is severe aggradation in the lower half mile of the channel that has prompted landowners to build flood control structures (e.g. dikes, retaining walls, anchored logs) that concentrate flow and increase scour potential. The lower 0.5 miles of the stream was moved into an artificial channel early this century. Dredged material placed on either bank functions as dikes. Non-native vegetation has colonized the dikes, further constricting the channel. Cycles of aggradation, flooding, and dredging have resulted. In 1997, the mouth of the stream was perched well above the estuary, creating a barrier to upstream migration (Ames et al. 2000).

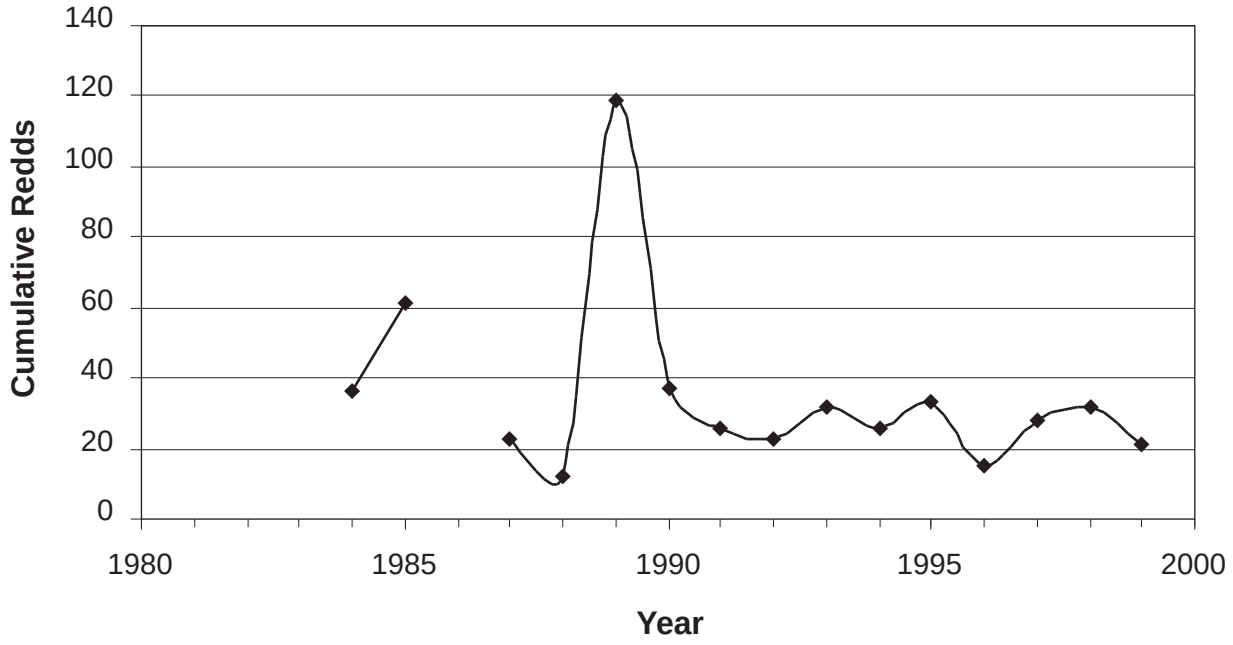
There has been limited habitat assessment done in Jimmycomelately Creek. The mainstem and West Fork are predominantly riffles, characterized by high summer temperature. Comparison with 1978 surveys suggests increased channel width and reduced pool area. In habitat that provides summer rearing for coho salmon, pools comprise only 10.4 percent of the channel area. Culverts in the upper watershed are too small, causing sediment deposition at their upstream ends, and presenting barriers to migration at low flow (McHenry et al. 1996).

14.4.2.2 *Riparian Zone*

In the lower 1.5 miles of Jimmycomelately Creek, 34 percent of the riparian zone is forested, 12 percent is in agricultural use, and 7 percent is in residential use (Ames et al. 2000). Roads and dikes occupy 10 percent of the riparian zone. Trees are immature (i.e. less than 20 inches dbh) in the existing forested buffer, and 69 percent of the forested buffer is less than 66 feet wide. Bank armoring along the lower 0.5 mile has affected the natural function of the riparian zone.

14.4.2.3 *Sub-estuarine Zone*

The delta at the mouth of Jimmycomelately Creek was estimated to have originally covered 139.4 acres. Dike construction, fill, log storage, and road intrusion, which have reduced the area by more than 6 percent. Though log storage occupies less than 2 acres, benthic production beneath the log rafts has likely been affected by the accumulation of wood debris (Ames et al. 2000). The U.S. 101 corridor has isolated the non-tidal floodplain from the tidal delta.



Source: R. Cooper, WDFW, 2000 (personal communication).

Figure 14-4
Coho Spawning Escapement to Jimmycomelately Creek, 1984-1999

14.4.2.4 *Chum Salmon Limiting Factors*

The lack of LWD, the loss of side channels, and channel instability in the lower reach has reduced channel complexity and thereby the quality of chum salmon spawning habitat. Riparian buffers were eliminated in the lower reach, and adjacent wetlands were eliminated or isolated from the stream channel. A survey in 1990 found 0.09 pieces of LWD/m. Pool habitat is scarce; it comprises only 30 percent of the channel area, and pool frequency is low (9.0 channel widths). Confinement of the channel within hardened banks and dikes has caused aggradation, increased peak flows, increased scouring in spawning areas. Redd scour is the dominant limiting factor for chum salmon egg survival. The loss of channel complexity and re-routing of the channel through the lowest reach has decreased the ability of the stream to transport sediment through the system (Ames et al. 2000). These factors have had a high impact on spawning habitat quality (Ames et al. 2000).

Benthic food production has been reduced in the log storage area, west of the stream mouth, and the containment booms may disrupt the emigration of juvenile chum salmon. Isolation of the floodplain above high tide from the tidal delta has reduced the quality of subestuarine habitat and affected the migration of juvenile and adult chum salmon (Ames et al. 2000).

14.4.3 Restoration Activities

Restoration activities in this sub-basin are shown in Table 14-4.

Table 14-4. Summary of Completed Restoration Projects in the West Sequim Sub-basin

Stream	Date	Restoration Type	Description
Scholz Creek	1999	Riparian Restoration	SRFB Early Action
Fletcher Creek	1999		SRFB Early Action

A restoration project is planned for construction during the summer of 2000 in the Jimmycomelately Watershed. This project is sponsored by the Jamestown S'Klallam Tribe, the Washington Department of Transportation, Clallam County Conservation District and Clallam County, and would include acquisition of land, removal or modification of and existing county bridge and channel restoration to improve fish passage.

14.5 INSTREAM FLOW

Ecology and WDFW (1997) present optimum flows, developed from toe-width measurements, for Chicken Coop Creek, Dean Creek, Jimmycomelately Creek, and Johnson Creek. Species and lifestages considered were coho salmon, chum salmon and steelhead spawning, and steelhead rearing, as appropriate (see Table 6-1). Optimum instream flows for Chicken Coop Creek were 3 cfs year-round. Optimum instream flows for Dean Creek range from a low of 4 cfs for steelhead juvenile rearing to a high of 11 cfs for coho salmon spawning. Optimum instream flows for Jimmycomelately Creek range from a low of 10 cfs for steelhead juvenile rearing to a high of 44 cfs for steelhead spawning. Optimum instream flows for Johnson Creek range from a low of 5 cfs for steelhead juvenile rearing to a high of 65.7 cfs for chinook salmon and chum salmon spawning.

Hiss (1993) presents optimum flows for Jimmycomelately Creek, Johnson Creek, and Chicken Coop Creek. Species and lifestages considered were chum salmon, coho salmon and steelhead spawning, and coho salmon and steelhead rearing, as appropriate. An unnamed Sequim Bay tributary (17.0284) was determined to have no suitable measurement site (see Table 6-3).

The most westerly tributary to Sequim Bay in WRIA 17 is Johnson Creek. Bell Creek, which could be seen as a West Sequim Bay tributary, is in WRIA 18.

14.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS

14.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity

Data to characterize or predict future changes in land use and population were unavailable for the West Sequim Bay sub-basin. Given population growth to the region and the City of Sequim, additional population is expected in the sub-basin. Predicted trends for other types of land use are unknown. Where dense population densities are expected (e.g. City of Sequim and Sequim UGA), increased impervious area could cause increased surface water runoff and reduced groundwater recharge unless appropriate stormwater management practices are taken. Regarding areas slated for rural residential growth, little information is available regarding the effects of relatively low densities of impervious area on groundwater recharge. While the effects of increased paving in rural residential areas are not expected to be substantial, some reduction in recharge may be associated with conversion of forested lands to meadows and lawns.

14.6.2 Population Growth

West Sequim sub-basin population in 1996 and estimates of growth over the next 20 years was not available for this study. Based on existing zoning (refer to Exhibit 1), the population growth will most likely occur in the Sequim UGA, along the Sequim Bay shoreline and near the rural village of Blyn.

14.6.3 Potential Impacts of Growth on Water Demand

Population predictions were unavailable to assess the growth of groundwater demand in the West Sequim Bay sub-basin. Within the Sequim UGA, additional groundwater demand is likely to be met by the City of Sequim water system. Outside the UGA, increased demand is likely to be met by small public water systems and single family domestic wells.

14.6.4 Potential Impacts of Land Use and Growth on Habitat

Based on the available data, the factors that limit salmonid productivity in the sub-basin stem mostly from high sediment loading in the upper watershed. In the lower reaches of Jimmycomelately Creek, where limited quantitative habitat assessment has occurred, sediment erosion has aggraded the stream channel. Flood control structures, channel modification, and bank armoring has occurred to reduced the risk to local residents, but these structures have severely reduced the productive capacity of the stream for summer chum salmon and coho salmon. Aggradation of the lower reaches has also disconnected the sub-estuary from the stream delta, and, as a result, has affected the migration and survival of juvenile summer chum salmon. Habitat degradation is thought to be a primary factor contributing to the critically depressed status of summer chum salmon and coho salmon in Jimmycomelately Creek. Substantial increased density of development along lower Jimmycomelately Creek is not projected for the period through 2016.

Efforts have begun to restore the natural channel morphology and sediment transport process through the lower reaches of Jimmycomelately Creek. This is a complex effort involving reconstruction of roads and bridges, including the U.S. 101 bridge. Improving summer chum salmon egg survival will depend on re-structuring of the lower mile of stream to restore some degree of stability and sinuosity to the streambed, increase LWD in the stream, and connection to the floodplain.

14.6.5 Conservation Options

Water conservation options that may be applicable to water users in the West Sequim sub-basin are summarized below.

- Tiered Water Rate Structures
- Modification of Landscape Irrigation Practices
- Water Conservation in Water Supply Systems and Individual Homes
- Educational programs
- Water Conservancy Boards To Facilitate Water Rights Transfers

14.7 DATA SYNTHESIS AND INTEGRATION

Groundwater use in the West Sequim sub-basin is estimated to comprise a relatively high proportion (40 percent) of total recharge, but there are insufficient data to conclude that groundwater withdrawal strongly influences streamflow. The geomorphology of the sub-basin indicates that potential hydraulic connectivity is moderate in the lower reaches of Jimmycomelately Creek, Johnson Creek, Chicken Coop Creek, and Dean Creek, where the streams flow over deposits of glacial till. However, if the till deposit under the lower reaches of these streams is a principal aquifer, connectivity could be high. There are no streamflow data to quantify the hydrographs of any stream in the sub-basin.

14.8 DATA QUALITY, GAPS AND LIMITATIONS

In addition to the general data gaps identified for the entire WRIA, the following specific data gaps have been identified for this sub-basin:

14.8.1 Water Quality

Data gaps and limitations in this sub-basin are consistent with those discussed for the entire WRIA. Specific data quantity and quality limitations are as follows:

- Water quality data is limited spatially and temporally and ongoing ambient monitoring does not exist for freshwater features in this sub-basin

- Marine water quality and outfall data is not available for the numerous point sources that discharge to Sequim Bay.

14.8.2 Water Quantity

Water quantity data gaps have been identified for the entire WRIA and generally apply to the West Sequim Bay sub-basin. The following additional definition of data gaps is based on consideration of currently existing data, and provides additional detail where possible:

- While generalized hydrogeologic characterization of the West Sequim Bay sub-basin is relatively good (Thomas et al. 1999), additional detail is required regarding groundwater levels along the coast and hydrostratigraphy (occurrence of aquifers and aquitards) beneath portions of the Miller Peninsula. Existing hydrogeologic characterization does not define conditions in bedrock aquifers, which support domestic wells.

- Quantities of groundwater flow from bedrock to adjacent unconsolidated sediments are unknown. Such estimation can only be achieved with extensive hydrogeologic characterization, including definition of aquifer occurrence, aquifer properties, and groundwater level gradients.

- Stream flow for Jimmycomelately Creek

- Hydrologic analysis of drainage patterns and channel conditions in Jimmycomelately Creek.

14.8.3 Habitat

- Assessment of rearing habitat capacity for summer chum salmon in the sub-estuary, including effects of log storage on fry migration and food production.

- Quantification of the effects of scour and deposition on chum salmon and coho salmon egg survival in lower Jimmycomelately Creek.

- Habitat and fish population assessment in other West Sequim streams, e.g. Johnson Creek, Dean Creek, and Chicken Coop Creek.

- Catalog small unnamed streams that have potential to support cutthroat trout and possibly other salmonids.

14.8.4 In-stream Flow

Instream flow data gaps for this sub-basin are the same as that identified for the entire WRIA. There is sufficient information to develop instream flow recommendations and to proceed with the setting of instream flows in most of the larger streams in the basin.

15. MILLER SUB-BASIN

15.1 SUB-BASIN DESCRIPTION

The Miller sub-basin is located on a peninsula between Discovery Bay and Sequim Bay (Figure 15-1).

15.1.1 Surface Water Features

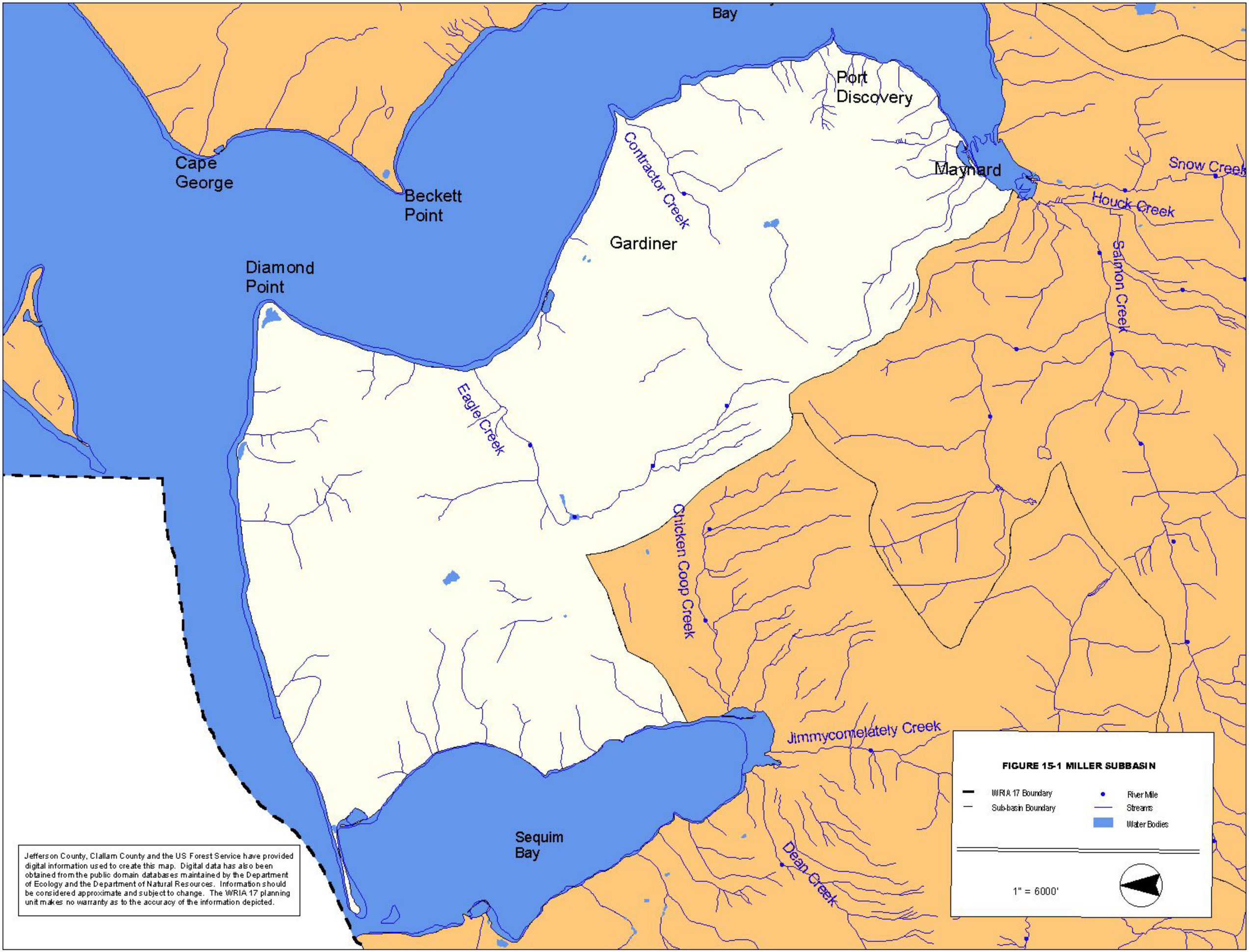
Eagle Creek and Contractors Creek are the two main freshwater features in this sub-basin; however, most of the sub-basin drains through small unnamed streams directly to either Discover Bay or Sequim Bay.

Contractors Creek is approximately 2.9 miles long and discharges to Discovery Bay near Carr Point. The stream corridor is located primarily on commercial forest land, and no agricultural uses are currently known to exist within the stream corridor. Recent logging operations in the headwaters has removed most vegetation from Type 4 and 5 stream corridors (PSCRBT 1992).

Eagle Creek is approximately 9.6 miles in length and has a watershed of 54 square miles. Land use in the stream corridor is primarily commercial forest, although pastures border approximately one mile of the stream and livestock has access to the stream in a few locations in the lower watershed (PSCRBT 1992). A dam was constructed near the mouth and a small pond was constructed downstream of Hwy 101. The dam was identified as a fish passage barrier and the small pond intercepts and stores flow in the creek, which dries up the channel for approximately 1.5 miles downstream except during heavy storm events (PSCRBT 1992).

15.1.2 Groundwater Features

Hydrogeologic characterization of the Miller sub-basin includes existing maps of surficial geology, and various regional hydrogeologic studies (Grimstad and Carson 1981; PGG and EES 1994; Associated Earth Sciences 1991; Thomas et al. 1999). All four studies provide cross-sections through the area, with more detail and text descriptions in the latter two studies. The sub-basin is characterized by extensive areas covered with till and narrow exposures of alluvium, recessional and advance outwash along the coast. Bedrock is present in the southeast portion of the sub-basin, and extends to depths of 1,000 feet on the north end of the Miller Peninsula. It should be noted that previous mapping showing bedrock in the middle of the peninsula has been superseded by more recent work showing thick sequences of unconsolidated sediments. The principal aquifer system beneath the till is relatively stratified, and has been characterized in a recent USGS study of the Sequim-Dungeness area (Thomas et al, 1999). The study identified six hydrostratigraphic units overlying bedrock: the “shallow aquifer”, the “upper confining bed”, the “middle aquifer”, the “lower confining bed”, the “lower aquifer”, and undifferentiated unconsolidated deposits. The shallow aquifer is primarily composed of Vashon glacial sediments. Both the middle and deep aquifer (where present) are composed of pre-Vashon materials, and extend beneath Sequim Bay into the Miller sub-basin. Sedimentary textures can vary greatly within the aquifer units identified. The confining beds are generally fine grained, but may contain discontinuous lenses of water bearing sand and gravel. The USGS study (ibid)notes that these generalized hydrostratigraphic units become more difficult to discern beneath the Miller Peninsula due to data scarcity and variations in both sedimentary texture and thickness. . The Associated Earth Sciences study (1991) employs a different classification system and nomenclature, but also notes the stratified nature of aquifers and aquitards. In a few cases, relatively high well yields have been noted in deeper aquifers beneath the Miller sub-basin.


Bay
Port Discovery
Cape George
Beckett Point
Contractor Creek
Maynard
Snow Creek
Houck Creek
Gardiner
Salmon Creek
Diamond Point
Eagle Creek
Chicken Coop Creek
Jimmycomelately Creek
Sequim Bay
Dean Creek
FIGURE 15-1 MILLER SUBBASIN
WRIA 17 Boundary
Sub-basin Boundary
River Mile
Streams
Water Bodies
1" = 6000'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.

15.1.3 Land Use

The majority of the land use in the Miller sub-basin is within rural residential lands, which comprise approximately 84 percent of the sub-basin with the primary residential land use of one dwelling unit per five acres. Commercial forest comprises about seven percent of the sub-basin and public lands comprise about Existing land use in this sub-basin is shown in Table 15-1.

Table 15-1. Miller Sub-basin Land Use

Description	No. of Parcels	Acres	% of Total
Urban Residential	NA	564	4.2%
Industrial Residential	NA	36	0.3%
Public	NA	82	0.6%
Rural Residential (1:5)	549	5,254	39.5%
Rural Residential (1:10)	80	873	6.6%
Rural Residential (1:20)	NA	138	1.0%
Rural Residential (1:20)	494	4,921	37.0%
Rural Forest	3	122	0.9%
Commercial Forest	13	914	6.9%
Resource Based Industrial Zone (Center, Gardiner	2	25	0.2%
Tidelands	45	41	0.3%
Roads and Right of Ways	98	320	2.4%
Totals	**1,284**	**13,290**	**100.0%**

N/A = Not Available

Source: Jefferson County and Clallam County GIS (2000). Parcel data for Jefferson County only.

15.2 WATER QUALITY

15.2.1 Surface Water Quality

Surface water quality data for this sub-basin is limited. Rubida conducted FC monitoring on Contractors Creek at two locations between 1988 and 1989 (Rubida 1989 as seen in PSCRBT 1992). In general, the results showed that this creek has low FC levels (Table 15-2).

Table 15-2. Fecal Coliform concentrations in Contractors Creek 1988-1989

Survey Areas	FC GMV (FC/110MC)	Compliance
Near mouth	15.6	Yes
Highway 101	13.9	Yes

Source: Rubida 1989 as seen in PSCRBT 1992

15.2.2 Marine Water Quality

The Miller sub-basin drains to Discovery Bay and Sequim Bay. Discovery Bay is discussed in the Salmon-Snow Sub-basin section, and Sequim Bay is discussed in the West Sequim Bay Sub-basin section.

15.2.3 Inventory of Potential Surface Water Contaminant Sources

15.2.3.1 *Point Sources*

Four point sources of pollution have been identified in this sub-basin. Point sources, each with an individual NPDES permit, are summarized below from Ecology (1999a):

- Westerman Dam No 2
- Stoddard International
- Westerman Dam No 1
- J and D East Gravel Pit

It is noted that NPDES point source locations have been provided by Ecology and in some cases may depict facility names and locations that may not be entirely representative of existing conditions. The Ecology database does also not distinguish between stormwater and/or wastewater permits. No specific monitoring data or compliance problems were available for these specific point sources.

15.2.3.2 *Non-Point Sources*

Two specific areas of non-point pollution were identified in this sub-basin (Table 15-3). However, other sources such as agricultural practices and failing septic systems may also contribute non-point pollution to local streams and Discovery Bay.

Table 15-3. Summary of Non-Point Source Pollution in the Miller Sub-basin

Location	Description of Pollutant
Contractor Creek	Undersized ditches and lack of culverts cause roads to flood, which supply a source of sediment to intermittent streams and wetlands downstream (PSCRBT 1992).
Diamond Point	Several tightlines near Diamond Point convey non-point source pollution straight into Discovery Bay (Ecology 1998b).

15.2.4 Summary of Surface Water Trends and Compliance Problems

The study conducted by Rubida (1989) indicated that FC concentrations in Contractors Creek do not exceed state water quality standards. No other water quality data was available in this sub-basin. Discovery Bay is discussed in the Salmon-Snow Sub-basin, and Sequim Bay is discussed in the West Sequim Bay sub-basin.

15.2.5 Groundwater Quality

Chloride concentrations in the Miller Sub-Basin are mapped on Exhibit 4. A cluster of seven wells with chloride concentrations exceeding 100 mg/l occurs near Gardiner. Six of these wells are located along the coast, and the seventh occurs about 3,000 feet inland. An eighth well in the Gardiner vicinity exhibits a chloride concentration between 50-100 mg/l. Elevated chloride is observed in two wells in the Diamond Point vicinity, one in the 50-100 mg/l range and the other with over 100 mg/l chloride. Elevated chloride in coastal areas is also observed in isolated wells south of Point Discovery and on the eastern shore of Sequim Bay. A second inland well, about three miles west of Gardiner, also shows an elevated chloride concentration (100-250 mg/l). Elevated concentrations in inland wells suggest natural (as opposed to pumping induced) chloride at these locations. While elevated concentrations are more common in coastal areas of the Miller Sub-Basin, the level of analysis performed in this report could not be used to

differentiate between natural and pumping-induced sources. In any case, caution should be exercised before developing additional groundwater sources from coastal areas with known elevated chloride.

The groundwater system of the Miller Peninsula is highly stratified with a series of shallow and deep aquifers. Previous hydrogeologic characterization has shown that inland wells completed in the deep "Lower Discovery Aquifer" (approximately 150 to 300 feet below sea level) show relatively high aquifer permeability and hydraulic head (David Evans and Associates 1991). It has been suggested that the Lower Discovery Aquifer is less susceptible to saltwater intrusion based on this information (ibid.). However, isolated wells located west of Diamond Point and on the eastern shore of Sequim Bay are completed at depths of 321 and 500 feet below land surface respectively, and both show chloride concentrations above 250 mg/l. If these wells have a hydraulic connection to the Lower Discovery Aquifer, drawdown associated with additional pumping would further reduce head and possibly increase chloride concentrations. Supplemental hydrogeologic analysis may be required to determine whether deep coastal wells are indeed less susceptible to saltwater intrusion from inland pumping in the Lower Discovery Aquifer.

Nitrate concentrations are available from only eight wells in the Miller Sub-Basin, all of which occur in the natural background range (Exhibit 5). No incidents of anthropogenic groundwater contamination have been diagnosed in the Miller Sub-Basin.

15.3 WATER QUANTITY

15.3.1 Estimate of Water Quantity

15.3.1.1 *Groundwater Quantity*

Groundwater recharge estimated for the Miller sub-basin is approximately 8,100 af/yr, and averages 5.8 in/yr over the entire area. Exhibit 6 shows that predicted recharge typically falls within the 5 to 10 in/yr range, but occurs between 0-5 in/yr on the northern tip of the peninsula. Similar to other areas with low precipitation, values of predicted recharge are largely independent of the presence of glacial till. Precipitation, which averages 25 in/yr over the sub-basin, is the limiting factor for recharge. Throughout the sub-basin, precipitation minus plant evapotranspiration does not exceed the transmitting capacity of the till. Approximately 76 percent of the sub-basin is covered by shallow till and 16 percent is covered by bedrock. Rejected recharge (runoff) is predicted to be largely absent from till-covered areas due to the relatively low rainfall.

15.3.2 Surface Water Quantity

No surface water quantity information was available for this sub-basin.

15.3.3 Estimate of Water Use and Allocation

15.3.3.1 *Groundwater Use and Allocation*

Exhibit 11 shows the spatial distribution of groundwater use in the Miller sub-basin. The total groundwater withdrawal, assuming a domestic use of 250 gpd, is 312 af/yr. Approximately 51 percent of this total use is estimated from water rights and claims for irrigation purposes, and is qualified as being "lower accuracy" data. The remaining 49 percent (153 af/yr) is based on various sources for domestic and commercial uses, and is believed to be relatively high quality data. The groundwater withdrawal estimated for single family domestic wells (43 af/yr) is based on a count of well logs from the Clallam and Jefferson county well databases, and likely underestimates the full single domestic withdrawal.

While total domestic use is likely higher than estimated due to the presence of unreported domestic wells in the sub-basin, the *consumptive* portion of domestic groundwater use is likely to be much lower because all households in the sub-basin use septic systems.

In the Miller sub-basin, 33 groundwater rights have been issued for a total of 1,045 af/yr. The spatial distribution of groundwater rights is presented in Exhibit 8. Figure 15-2, a pie chart of groundwater rights by use, shows that approximately 95 percent of the total allocation is for domestic uses, 4 percent is for irrigation, and 1 percent if for commercial and industrial.

There are 155 well logs for the Miller sub-basin contained in the Clallam and Jefferson county well databases, translating to a potential exempt allocation of 868 af/yr. More unregistered wells are likely to exist, however only a small portion of this exempt allocation is likely to be actually put to use. There are four water right applications in the Miller sub-basin, requesting a total Qi of 1,740 gpm. Exhibit 9 presents the locations of these applications, and Table 4-2 lists their stated purpose of use. The three applications (representing 1,700 gpm combined) are for domestic multiple and irrigation. The fourth is for a mixture of four uses.

There are 118 groundwater claims in the sub-basin. Table 4-3 lists claims by use, and shows that 35 of these claims list irrigation as a principal use. Typically, only a portion of claims listing irrigation as a purpose-of-use list numbers of irrigated acres. In the Miller sub-basin, water use associated with the reported numbers of irrigated acres amounts to 116 af/yr. If each claim is also assumed to include a domestic use, total claimed groundwater can be estimated at about 234 af/yr. The portion of these claims that have been actually put to use, and would qualify for a water right, is unknown. A map of the distribution of groundwater claims is presented on Exhibit 10.

15.3.3.2 *Surface Water Use and Allocation*

Table 15-4 shows the relative distribution of consumptive use water rights in the Miller sub-basin. The largest use of water is for irrigation, comprising 92 percent of the total instantaneous quantity and 98 percent of the total annual quantity. The next largest use is for domestic single households followed by fish propagation. Figure 15-2 presents pie charts of the relative distribution of water rights. The total consumptive use rights are 1.02 cfs and 146 af/yr annual quantity. Claims data indicate that 0.24 cfs are claimed with an annual quantity estimated at 24 af/yr. The claims data is not reflected on the pie charts.

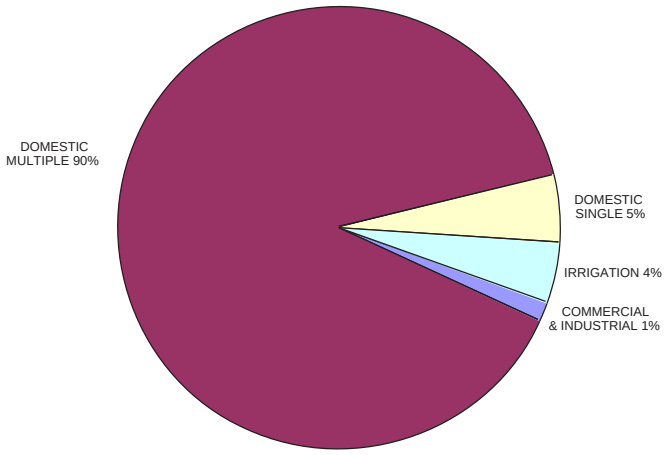
Table 15-4. Analysis of Surface Water Allocation in Miller Sub-basin

Purpose	Percent QI	Percent QA
DS	6%	2%
FR	2%	0%
IR	92%	98%

Explanation of Purpose Codes:

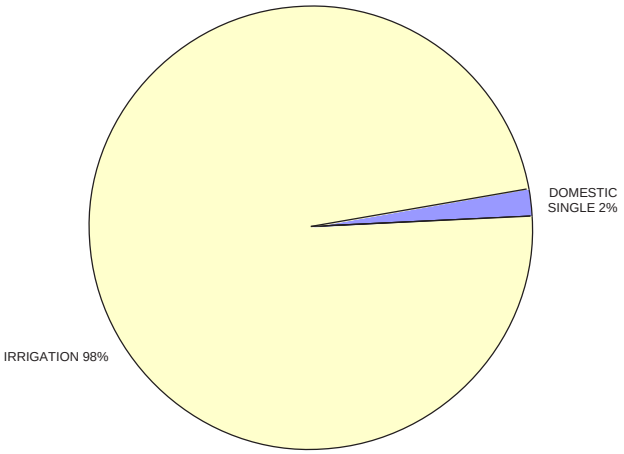
CI	Commercial and Industrial Manufacturing	FS	Fish Propagation
DM	Domestic Multiple	IR	Irrigation
DS	Domestic Single	MI	Mining
MU	Municipal	ST	Stock Watering
FR	Fire Protection		

GROUNDWATER RIGHTS (QA) BY USE



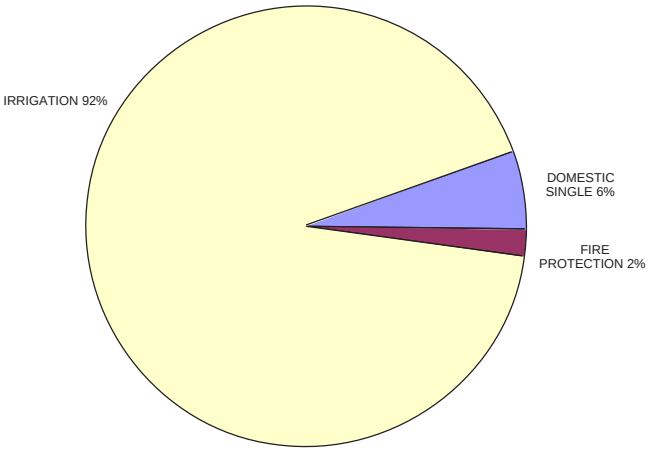
Note: total allocation = 1,045 af/yr, accounted by use = 965 af/yr, domestic exempt wells = 868 af/yr

SURFACE WATER RIGHTS (QA) BY USE



Note: total allocation = 146 af/yr, accounted by purpose 146 af/yr, no additional non-consumptive rights as Qa

SURFACE WATER RIGHTS (QI) BY USE



Note: total allocation = 1.0 cfs, accounted by purpose = 1.0 cfs, no additional non-consumptive rights as Qi

Source: Ecology WRATs database

Figure 15-2
Miller Sub-Basin Groundwater and Surface Water Rights and Use, Consumptive Use Only

15.3.4 Hydraulic Continuity Potential

Two major streams are identified in the Miller sub-basin, as shown on Exhibit 17. Eagle Creek flows predominantly over bedrock and glacial till, where it receives a "low" ranking of RHCP. At its mouth, the creek may cut down into advance outwash materials and therefore exhibit "high" RHCP with the principal aquifer. The degree of potential connection with advance outwash materials is unknown. The upper reaches of Contractor Creek also flow over glacial till and receive a low RHCP ranking. Near its mouth, the creek is surrounded by a deltaic deposit of recessional outwash. In this location the outwash is assumed to occur above the till, and the stream is assigned a "medium" RHCP ranking. At its mouth, the creek cuts down to sea level and intersects advance outwash sediments of the principal aquifer. It is assigned a "high" RHCP in this location.

15.4 HABITAT

Salmonid fish distribution and habitat quality are not described for the Miller sub-basin.

15.5 INSTREAM FLOW

Hiss (1993) presents optimum flows for Contractors Creek. Species and lifestages considered were coho salmon and steelhead spawning, and steelhead rearing. Optimum instream flows for Contractors Creek range from a low of 1 cfs for steelhead juvenile rearing to a high of 8 cfs for steelhead spawning. Two unnamed streams near Thompson Spit (17.0276 and 17.0277) were investigated, and found to have no suitable measurement sites (see Table 6-3).

15.6 FUTURE PROJECTION AND POTENTIAL IMPACTS

15.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity

Data to characterize or predict future changes in land use and population were unavailable for the West Sequim Bay sub-basin. Given population growth to the region, additional population is expected in the sub-basin. Predicted trends for other types of land use are unknown. If growth occurs in areas zoned for urban residential development, increased impervious area could cause increased surface water runoff and reduced groundwater recharge unless appropriate stormwater management practices are taken. The impacts on groundwater recharge associate with additional paving in rural residential areas are not well studied, but also not expected to be substantial. However, conversion of forested lands to meadows and lawns may reduce groundwater recharge in these areas.

15.6.2 Population Growth

Miller sub-basin population in 1996 and estimates of growth over the next 20 years was not available for this study. Based on existing zoning (refer to Exhibit 1), the population growth will most likely occur in the northwest Miller Peninsula area on one dwelling per 2 acre zoned land in Clallam County

15.6.3 Potential Impacts of Land Use and Growth on Habitat

Prediction of impacts to habitat due to population growth are hampered by lack of data on existing habitat and salmonid use in this sub-basin. Lack of data to characterize or predict future changes in population and/or land use also reduces ability to predict impacts. However, given that some growth is expected in

this sub-basin, potential impacts may occur on estuarine and near shore marine habitat through bulkheads, clearing of vegetation and erosion. Increased impervious area could also cause increased surface water runoff and peak flows, as well as potential surface water quality impacts. Conversion of forested lands to meadows and lawns may reduce groundwater recharge and stream base flow, as well as potentially reduce riparian areas.

15.6.4 Potential Impacts of Growth on Water Demand

Population predictions were unavailable to assess the growth of groundwater demand in the Miller sub-basin. Current groundwater withdrawals in the sub-basin are supplied by both small public water systems and single family domestic wells. Future demand will likely be met by similar sources.

15.6.5 Conservation Options

Water conservation options that may be applicable to water users in the Quimper Sub-basin are summarized below.

- Tiered Water Rate Structures
- Modification of Landscape Irrigation Practices
- Water Conservation in Water Supply Systems and Individual Homes
- Educational programs
- Water Re-Use
- Increased Storage, Either Through Surface Storage Or Aquifer Storage
- Water Conservancy Boards To Facilitate Water Rights Transfers
- Improve Water Measurement Network
- Implement water conservation at Port Townsend Paper Company

15.7 DATA SYNTHESIS AND INTEGRATION

The low amount of existing water quality, water quantity and habitat data limits the ability to conduct a data synthesis and integration in the Miller sub-basin. Existing groundwater quality data suggests that elevated chlorides exist in shoreline development areas; however, insufficient data was available to determine whether these concentrations are natural or pumping induced.

There is one section in this sub-basin were groundwater use exceeds 60 ac-ft/yr. This area is generally identified as areas where less than 10 inches of recharge would be expected per year. Groundwater use in this sub-basin is estimated at only 4 percent of recharge.

The lower portion of Contractor Creek has been identified as a location of potential high hydraulic continuity. Surface water rights also exceed 0.2 cfs in the lower segment of Contractor Creek. These factors suggest that the lower segment of Contractor Creek may be at risk for low base-flow and fish habitat. Steelhead, cutthroat and coho salmon are known to use the lower portions of this stream; however, little information is available on stock status and habitat in lower Contractor Creek.

15.8 DATA QUALITY, GAPS AND LIMITATIONS

In addition to the general data gaps identified for the entire WRIA, the following specific data gaps have been identified for this sub-basin.

15.8.1 Water Quality

The general recommendations for the entire WRIA 17 apply to this sub-basin. No specific data gaps have been identified.

- Very little surface water data is available for this sub-basin. Existing data is available only for Contractor Creek and is greater than 5 years old.

15.8.2 Water Quantity

Water quantity data gaps have been identified for the entire WRIA and generally apply to the Miller sub-basin. The following additional definition of data gaps is based on consideration of currently existing data, and provides additional detail where possible:

- While hydrogeologic characterization has been performed for the Miller Peninsula and a relatively stratified system of aquifers and aquitards is noted, studies suggest that subsurface variability makes hydrogeologic interpretation somewhat complicated (Thomas et al, 1999). Additional characterization is likely needed to better define the lateral extent and textural variation of aquifers beneath the peninsula.

- While prolific wells are completed in deep aquifers beneath the Miller Peninsula, chloride concentrations along the coast suggest vulnerability to saltwater intrusion. Groundwater level elevations in coastal wells are currently unavailable to assess the degree to which pumping from deep aquifers may affect coastal water levels and potential saltwater intrusion.

- Quantities of groundwater flow from bedrock to adjacent unconsolidated sediments are unknown. Such estimation can only be achieved with extensive hydrogeologic characterization, including definition of aquifer occurrence, aquifer properties, and groundwater level gradients

15.8.3 Habitat

Data on fish habitat for the small streams in this sub-basin is very limited. Many small unnamed streams have potential to support cutthroat trout and possibly other salmonids. The cumulative importance of these small streams should be considered. Cataloging of these streams for potential fish presence and habitat should be considered and would help to provide a more complete understanding of fish distribution in this sub-basin.

15.8.4 In-stream Flow

Instream flow data gaps for this sub-basin are the same as that identified for the entire WRIA. There is sufficient information to develop instream flow recommendations and to proceed with the setting of instream flows in most of the larger streams in the basin.

16. QUIMPER SUB-BASIN

16.1 BASIN DESCRIPTION

The Quimper sub-basin is located on the Quimper Peninsula in the northern portion of WRIA 17 and has portions that discharge to Port Townsend Bay, Discovery Bay, Admirality Inlet, Puget Sound and the Straight of Juan de Fuca (Figure 16-1).

16.1.1 Surface Water Features

There are no notable stream features in the Quimper sub-basin and the streams that drain the area are generally intermittent and high gradient (PSCRBT 1992).

16.1.2 Groundwater Features

Hydrogeologic characterization in the Quimper sub-basin is limited to existing maps of surficial geology, generalized geologic cross through the area (EES and PGG 1994; Grimstad and Carson 1981), discussion of potential well yields (ibid), and mapping of miscellaneous selected static groundwater levels (Grimstad and Carson 1981). The sub-basin is characterized by extensive areas covered with dense basal till, by broad channels eroded through the till into underlying principal aquifer materials, and by the presence of loose ablation till overlying portions of the basal till. Generalized surficial geology for the Quimper sub-basin can be seen on Exhibit 17. Principal aquifer materials are predominantly composed of Vashon advance outwash, pre-Vashon stratified glacial drift and interglacial deposits. Exposures of the advance outwash are noted in a channel feature in the western portion of the peninsula and near Glen Cove. The channel feature has been infilled with recessional outwash, and may not penetrate through the till toward its northern extent. A large area of ablation till, located north-northeast of the channel, lies above the basal till and may contain perched groundwater. Bedrock exposures are not noted in the sub-basin. Potential well yields on the peninsula range from low to high, however mapped groundwater levels on the northern peninsula are relatively low and the potential for saltwater intrusion may be a concern. The mapped groundwater levels do not indicate associated completion aquifers.

16.1.3 Land Use

The majority of the land use in the Quimper sub-basin is rural residential lands, which comprise approximately 59 percent of the sub-basin with the primary residential land use of one dwelling unit per five acres. The Quimper sub-basin includes the developed areas of Port Townsend and Cape George. Commercial forestry, rural forestry, and inholding forestry land use zones comprise approximately 11 percent of total. The Port Townsend UGA covers 7,396 acres, or just over 21 percent of the sub-basin. Existing land use in this sub-basin is shown in Table 16-1.

16.2 WATER QUALITY

16.2.1 Surface Water Quality

No freshwater quality data is currently available for this sub-basin.

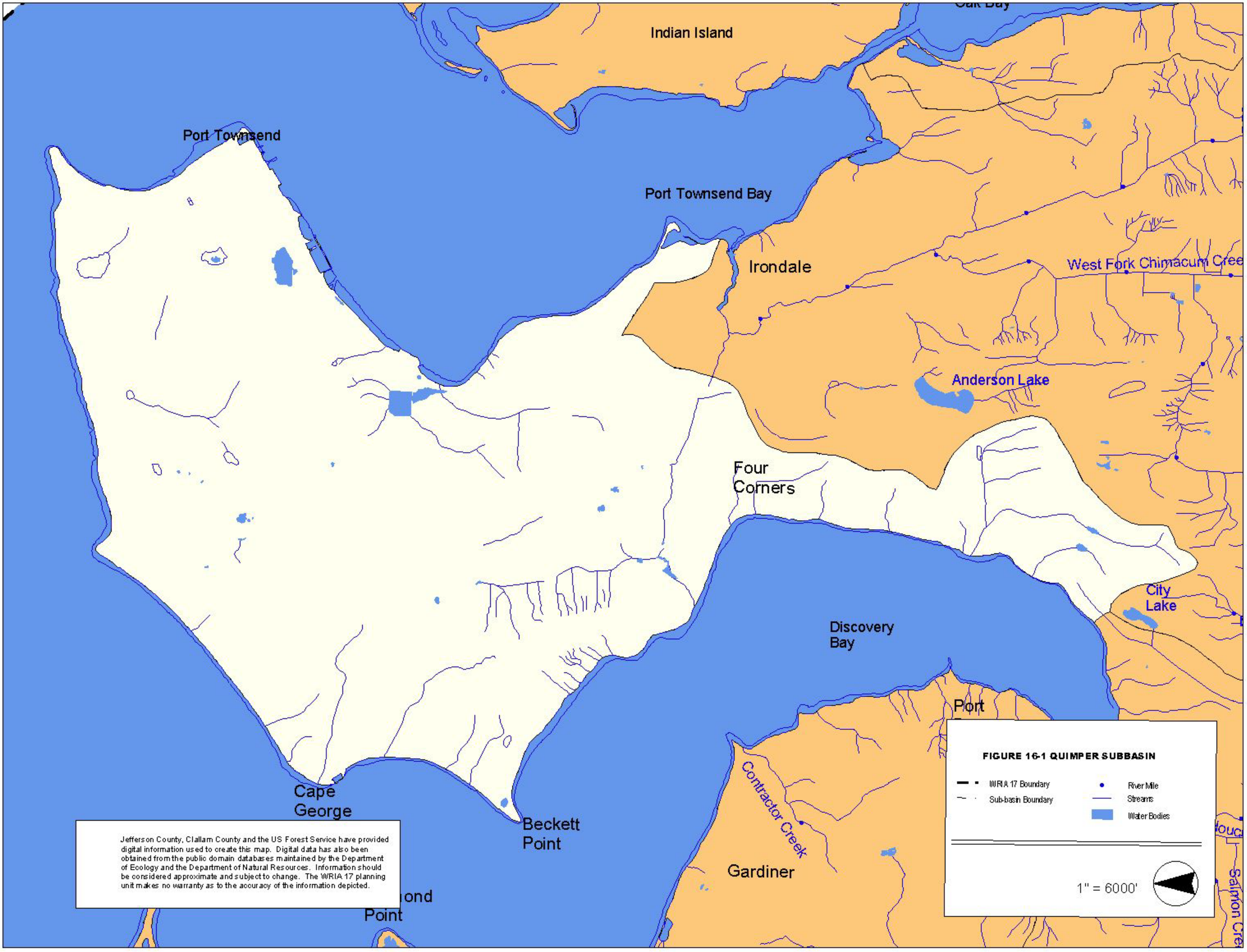

Indian Island
Port Townsend
Port Townsend Bay
Irondale
West Fork Chimacum Cree
Anderson Lake
Four Corners
City Lake
Discovery Bay
Port
Contractor Creek
Gardiner
Cape George
Beckett Point
Point
Salmon Cre
FIGURE 16-1 QUIMPER SUBBASIN
WRIA 17 Boundary
Sub-basin Boundary
River Mile
Streams
Water Bodies
1" = 6000'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.

Table 16-1. Quimper Sub-basin Land Use

Description	No. of Parcels	Acres	% of Total
Rural Residential (1:5)	3,942	5,878	32.4%
Rural Residential (1:10)	229	1,874	10.3%
Rural Residential (1:20)	368	2,921	16.1%
Parks, Preserves, Recreation	237	125	0.7%
Rural Forest	2	41	0.2%
Commercial Forest	27	1,732	9.5%
Inholding Forest	2	30	0.2%
Heavy Industry (Mill)	38	252	1.4%
Airport and Waste Management Facilities	36	507	2.8%
Port Townsend Urban Growth Area*	7,396	3,861	21.3%
Glen Cove Industrial Area	188	68	0.4%
Tidelands	72	108	0.6%
Roads and Right of Ways	270	742	4.1%
Totals	**12,807**	**18,139**	**100.0%**

Parks, Preserves, and Recreation areas in Port Townsend are accounted for in Parks category. The roads in Port Townsend are accounted for in Roads and Right of Way category.

Source: Jefferson County (2000)

16.2.2 Marine Water Quality

The Quimper Sub-basin discharges to Discovery Bay and Port Townsend Bay. Discovery Bay is discussed in the Salmon-Snow Sub-basin and Port Townsend Bay is discussed in the Section 6 Chimacum Sub-Basin. Areas that have been closed for shellfish harvesting are shown on Exhibit 3 (PSEP 1992).

16.2.3 Inventory of Potential Surface Water Contaminant Sources

16.2.3.1 *Point Sources*

The Quimper sub-basin has almost 50 NPDES permits for point sources. Most of these permits are associated with industrial uses within the City of Port Townsend and discharge into Port Townsend Bay. NPDES permits listed by Ecology (1999a) are as follows:

- Port Townsend STP
- Milwaukee Railroad ROW
- WA Parks Fort Worden State Park
- Lindsey Clean Up Site
- Alleniana, Inc.
- Pt Townsend City
- Fowler Park Roadbed
- Johnny K Design
- Port Townsend Gas MFG
- WA DOT PIT Y119
- Port Townsend Paper Company
- Port Townsend PW Cape George Pit
- Erickson Auto Body
- Admiral Marine Works, Inc. Haines St
- Furniture Clinic
- Lakeside Industries Cape George Pit
- Baird Boat Co
- Port Townsend Foundry
- Port Townsend Shipwrights
- Integrated Marine Systems

- Fleet Marine Inc
- US WEST Port Townsend
- USWCOM Port Townsend Co
- WA DOT Port Townsend Ferry Terminal
- Port Townsend Texaco
- Chevron Bulk Plant
- Powell Drug Lab
- Port Townsend Elks Club 0317
- Jefferson County International Airport
- Port Townsend Motorsport Inc
- Russ Auto Truck Clinic
- Circle and Square Inc
- Admiral Marine Works Inc Seton Rd
- Jefferson County Transit
- Hilltop Texaco Port Townsend
- All City Autobody Towing Inc
- Cecil M Lange Son Inc
- Port Townsend School District 50 MT WV ES
- Chevron USA Inc Bulk Terminal
- Dockside Cleaners
- First Place Propeller and Impeller
- Patterson Automotive
- Fred Hill Materials Port Townsend
- USPS Discovery Bay
- Puget Sound Power and Light Co Pt Townsend
- WA DOT PIT Y127

It is noted that NPDES point source locations have been provided by Ecology and in some cases may depict facility names and locations that may not be entirely representative of existing conditions. The Ecology database does also not distinguish between stormwater and/or wastewater permits. No specific monitoring data or compliance problems were available for these specific point sources. An additional source of pollution not identified in the Ecology database are combined sewer overflows (CSO) in the city of Port Townsend. The City is currently working to correct CSO problems,

16.2.3.2 *Non-Point Sources*

Residential and urban areas have been identified as the primary non-point sources in this sub-basin. Table 16-2 summarizes these specific locations. The City of Port Townsend is considered a source of non-point pollution in Port Townsend Bay and runoff from urbanized portions of the city currently run into Port Townsend Bay untreated (Ecology 1998b).

Table 16-2. Summary of Non-point Source Pollution in the Quimper Sub-basin

Location	Description of Pollutant
Cape George	High potential for FC contamination due to a high concentration of residential septic systems that may fail due to the location and high water table (Gray and Osbourne 1988)
Beckett Point	High potential for FC contamination due to a high concentration of residential septic systems that may fail due to the location and high water table (PSCRBT 1992)
Port Townsend	Urban and residential development
Four Corners	Urban and residential development

In addition to residential and urban uses, the relatively high abundance of farms and livestock rearing activities in this sub-basin may also be a non-point source of pollutants.

16.2.4 Summary of Surface Water Trends and Compliance Problems

No freshwater data has been collected in this sub-basin. The Quimper sub-basin discharges to Discovery Bay and Port Townsend Bay. Discovery Bay is discussed in the Salmon-Snow Sub-basin, and Townsend Bay is discussed in the Chimacum Sub-Basin. Ecology has placed Port Townsend Bay on the 1996

303(d) list for exceeding PCB criteria (Ecology 1998a). However, the Bay was removed from the 1998 list when sediment sampling conducted near the outfall of the Port Townsend paper mill indicated that PCB concentrations were below established criteria.

16.2.5 Groundwater Quality

Chloride concentrations in the Quimper Sub-Basin are mapped on Exhibit 4. Isolated instances of chloride concentrations exceeding 100 mg/l occur at Kala Point, in a well along the southeast coast of Discovery Bay, and in two wells inland of the Admiralty Inlet coastline between Cape George and McCurdy Point (both coastal and inland wells). Two other wells in this inland vicinity show mildly elevated chloride concentrations (50 to 100 mg/l). Forbes and CH2M Hill (1993) notes that the chloride concentration in a well at Glen Cove showed an increase in chloride concentration from 27 mg/l in 1978 to 52 mg/l in 1993. The higher-end value is not shown on Exhibit 4 due to averaging techniques, and no attempt has been made to assess the inherent variability in chloride concentration between any two sampling events. No chloride data are available in the Port Townsend vicinity, where domestic wells are absent due to the use of the City's water system.

Nitrate concentrations in the Quimper Sub-Basin are mapped on Exhibit 5. Elevated nitrate concentrations are scattered across the interior of the sub-basin, with a minor cluster suggested near the intersection of State Route 19 and State Route 20. However, given the low density of wells sampled near this intersection, a really extensive nitrate contamination cannot be inferred.

Groundwater contamination has been diagnosed at seven sites in Port Townsend due to leaking underground storage tanks or other sources of hazardous materials. The sources reviewed provide no published evidence that these cases of groundwater contamination have compromised drinking water for other groundwater users.

16.3 WATER QUANTITY

16.3.1 Groundwater Quantity

Groundwater recharge estimated for the Quimper sub-basin is approximately 8,980 af/yr, and averages 5.8 in/yr over the entire area. Exhibit 6 shows that recharge varies from 5 to 10 in/yr and is largely independent of the presence of glacial till. Precipitation, which averages 21.5 in/yr over the sub-basin, is the limiting factor for recharge. Throughout the sub-basin, precipitation minus plant evapotranspiration does not exceed the transmitting capacity of the till. Approximately 60 percent of the sub-basin is covered by shallow till. Rejected recharge (runoff) is predicted to be largely absent from till-covered areas due to the relatively low rainfall.

16.3.2 Surface Water Quantity

Streamflow data is unavailable for all creeks within this sub-basin.

16.3.3 Estimated Water Use and Allocation

16.3.3.1 *Groundwater Use and Allocation*

Exhibit 11 shows the spatial distribution of groundwater use in the Quimper sub-basin. The total groundwater withdrawal, assuming a domestic use of 250 gpd, is 654 af/yr. Approximately 33 percent of this total use is estimated from water rights and claims for irrigation purposes, and is qualified as being "lower accuracy" data. The remaining 67 percent (439 af/yr) is based on various sources for domestic

and commercial uses, and is believed to be relatively high quality data. Outside of areas supplied by the Port Townsend water system, reliance on septic tanks makes the *consumptive* portion of domestic groundwater use much lower than the numbers noted above. In addition, a portion of customers purchasing surface water from the City (and *all* of the customers purchasing surface water from the Public Utilities District via the City) rely upon septic systems.

In the Quimper sub-basin, 38 groundwater rights have been issued for a total of 1,817 af/yr. The spatial distribution of groundwater rights is presented in Exhibit 8. Figure 16-2, a pie chart of groundwater rights by use, shows that approximately 91 percent of the total allocation is for domestic uses, 7 percent is for irrigation, and 2 percent is for mining.

Approximately 611 (exempt) single family wells are estimated for the Quimper sub-basin, translating to a potential exempt allocation of 3,423 af/yr. However, only a small portion of this exempt allocation is likely to be actually put to use.

There are four water right applications in the Quimper sub-basin, requesting a total Qi of 460 gpm. Exhibit 9 presents the locations of these applications, and Table 4-2 lists their stated purpose of use. Three applications are for domestic multiple use and one is for irrigation.

There are 80 groundwater claims in the sub-basin. Table 4-3 lists claims by use, and shows that 27 of these claims list irrigation as a principal use. Typically, only a portion of claims listing irrigation as a purpose-of-use list numbers of irrigated acres. In the Quimper sub-basin, water use associated with the reported numbers of irrigated acres amounts to 84 af/yr. If each claim is also assumed to include a domestic use, total claimed groundwater can be estimated at about 164 af/yr. The portion of these claims that have been actually put to use, and would qualify for a water right, is unknown. A map of the distribution of groundwater claims is presented on Exhibit 10.

16.3.3.2 *Surface Water Use and Allocation*

Table 16-3 shows the relative distribution of consumptive use water rights in the Quimper sub-basin. All water in the sub-basin is used for domestic multiple households. The total consumptive use rights are 0.02 cfs and 0 af/yr annual quantity. Claims data indicate that 1.8 cfs are claimed with an annual quantity estimated at 180 af/yr. The spatial distribution of surface water rights (Qa), claims (Qi), and claims (Qa) are shown in Exhibits 13, 14, and 15, respectively.

Table 16-3. Analysis of Surface Water Allocation in Quimper Sub-basin

Purpose	Percent Qi	Percent Qa
DM	100%	---

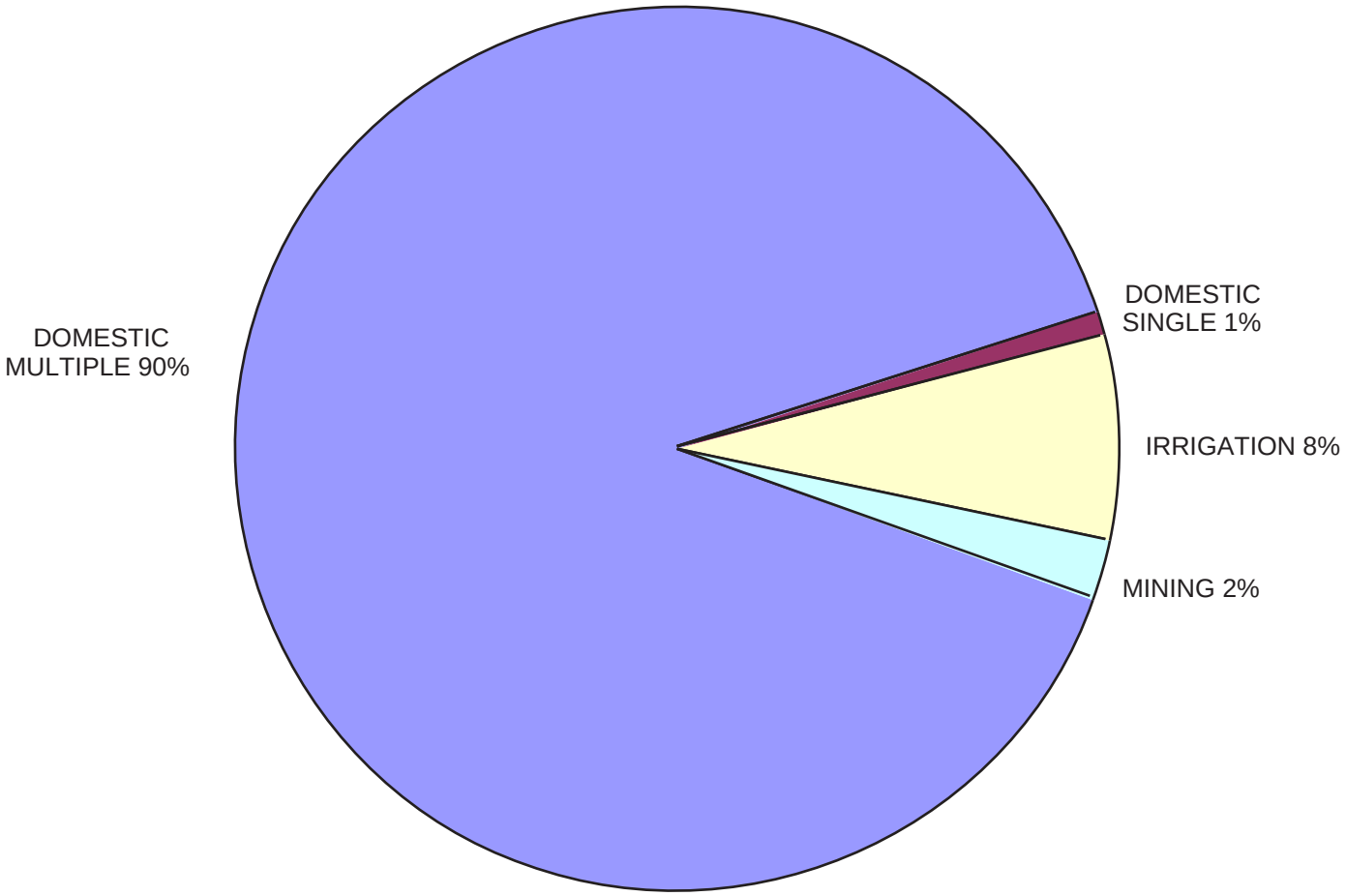
Explanation of Purpose Codes:

CI	Commercial and Industrial Manufacturing	FS	Fish Propagation
DM	Domestic Multiple	IR	Irrigation
DS	Domestic Single	MI	Mining
FR	Fire Protection	ST	Stock Watering

16.3.4 Hydraulic Continuity Potential

There is only one stream in the Quimper sub-basin shown by USGS topographic maps to have perennial flow. This stream flows into Discovery Bay near the Chevy Chase Golf Course, and is assigned a “high” RHCP due to its location in a channelized feature incised into the principal (Qva) aquifer. The stream is shown on Exhibit 17. The upper reach is marked with a dotted line to indicate ephemeral flow on the

GROUNDWATER RIGHTS (QA) BY USE



Note: total allocation = 1,817 af/yr, accounted by use = 1,751 af/yr, domestic exempt wells = 3243

Source: Ecology WRATs database

Figure 16-2
Quimper Sub-Basin Groundwater and Surface Water Rights and Use, Consumptive Use Only

USGS topographic map.

16.4 HABITAT

Salmonid fish distribution and habitat quality are not described for the Quimper sub-basin.

16.5 INSTREAM FLOW

Neither Ecology and WDFW (1997, 1999) or Hiss (1993) present optimum flows or toe-width study results for streams in this sub-basin. Chevy Chase Creek (17.0215) was investigated, and found to have no suitable measurement sites (Hiss 1993).

16.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS

16.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity

The data available to characterize future changes in land use in the Quimper sub-basin are generally limited to estimates of population growth. Table 16-1 shows that agricultural zoning is insignificant in the sub-basin (although farms do exist) and that areas zoned for commercial forest represent less than 10 percent of the sub-basin. Population projections and zoning patterns can be used to qualitatively predict changes in patterns of residential and associated commercial land use. Much of the increased population is expected to settle in the City of Port Townsend urban growth area. Unless appropriate stormwater management practices are applied to suburban and urban areas, densities of impervious area are likely to increase runoff and reduce groundwater recharge. In the rural residential portions of the Quimper sub-basin, the effects of associated densities of impervious surfaces are not expected to substantially reduce recharge. However, some reduction in recharge may be associated with conversion of forested lands to meadows and lawns. The effect of population increase on groundwater and surface water withdrawals is presented in Chapter 4.

16.6.2 Population Growth

In 1996, the Quimper sub-basin had 11,293 residents (Jefferson County 2000). Quimper sub-basin population growth over the next 20 years is estimated at 6,659 with 5,510 residents (83 percent of total) in the City of Port Townsend (Jefferson County 1998). Based on existing zoning (refer to Exhibit 1), the population growth will most likely be concentrated in the City of Port Townsend UGA. Additional growth would also likely occur on one dwelling unit per five acre zoned land that is located throughout this sub-basin.

16.6.3 Potential Impacts of Land Use and Growth on Habitat

Prediction of impacts to habitat due to population growth are hampered by lack of data on existing habitat and salmonid use in this sub-basin. However, given that some growth is expected in this sub-basin, potential impacts may occur on estuarine and near shore marine habitat through bulkheads, clearing of vegetation and erosion.

16.6.4 Potential Impacts of Growth on Water Demand

Population in the Quimper sub-basin is expected to increase by 59 percent between 1996 and 2016. Assuming that an average residence contains 2.2 people and uses 250 gpd, the projected increase of 6,659 people will cause an increased water demand of approximately 848 af/yr. Surface water is currently the principal source of residential and commercial supply for most of the sub-basin population, and is supplied by the City of Port Townsend water system from diversions on the Big and Little Quilcene Rivers.

About 17 percent of the total population increase in the sub-basin will occur outside of the City of Port Townsend (approximately 1,150 people). While a portion of this population will likely be served by City of Port Townsend surface water, conservative groundwater management analysis can be performed by assuming that all of this additional population will be met by groundwater. Current groundwater use in the sub-basin is near evenly divided between small public water systems and exempt wells. The related portion of additional water demand is 146 af/yr, or about 22 percent of current groundwater use (670 af/yr for residential, commercial and agricultural purposes). The increased demand also represents about 1.6 percent of estimated groundwater recharge, with current groundwater withdrawals estimated at 7.5 percent. However, as discussed in Section 4.4, comparison of groundwater pumping with recharge cannot be reliably used as a direct indicator of groundwater availability.

Portions of the population supplied by groundwater in the rural portions of the sub-basin rely on septic systems for wastewater disposal. These rural areas are assumed to largely correspond to the areas of population growth where groundwater resources will be used. In these rural areas, residential reliance on septic systems dictates that the consumptive portion of residential use is significantly less than the total residential groundwater withdrawal. Assuming that 87 percent of residential withdrawals are returned to the ground via septic infiltration (Solly et al. 1993), the actual increase in groundwater consumption would be on the order of 19 af/yr.

16.6.5 Conservation Options

Water conservation options that may be applicable to water users in the Miller Sub-basin are summarized below.

- Tiered Water Rate Structures
- Modification of Landscape Irrigation Practices
- Water Conservation in Water Supply Systems and Individual Homes
- Educational programs
- Water Conservancy Boards To Facilitate Water Rights Transfers

16.7 DATA SYNTHESIS AND INTEGRATION

Water quality, water quantity and habitat data is generally insufficient for a data synthesis and integration in the Quimper sub-basin. The Quimper sub-basin has the most dense development and highest population in WRIA 17. Although the majority of this sub-basin is served by the City's water system, there are two sections were groundwater use exceeds 60 ac-ft/yr. These areas are generally identified as areas where less than 10 inches of recharge would be expected per year. In general, however, groundwater use in this sub-basin is estimated at only 7.5 percent of recharge.

Land-use is typically urban or rural-residential, which suggests potential for water quality, water quantity and habitat impacts. In general, existing information suggests that elevated nitrate in groundwater could

be a potential issue in this sub-basin; however, insufficient groundwater quality data is available to confirm the potential causes and/or extent of the observed results.

16.8 DATA QUALITY, GAPS AND LIMITATIONS

16.8.1 Water Quality

Surface water data gaps and limitations in this sub-basin are consistent with those discussed for the entire WRIA. Specific data quantity and quality limitations are as follows:

- No freshwater monitoring has been conducted

16.8.2 Water Quantity

Water quantity data gaps have been identified for the entire WRIA and generally apply to the Quimper sub-basin. The following additional definition of data gaps is based on consideration of currently existing data, and provides additional detail where possible:

- A large area of ablation till occurs in the northern portion of the Quimper Peninsula, and likely contains a perched aquifer overlying basal till. The perched aquifer may discharge to an outwash channel located to the southwest. Exposures of advance outwash deposits along the southern portions of this outwash channel indicate that the channel cuts through the till in southern locations. The channel is likely not to cut through till in northern locations. The transition between a local perched groundwater system to the north and a direct connection to the principal aquifer system to the south, may control groundwater flow patterns. More information would be needed to better understand the flow system in this area.

- Relatively high development densities occur in the portions of the Quimper peninsula, particularly in the Port Townsend Urban Growth area. Better understanding of site runoff characteristics, soil permeabilities, and opportunities for stormwater infiltration may reduce potential hydrologic impacts associated with increased development.

- No streamflow data is available for this sub-basin.

16.8.3 Habitat

Data on fish habitat for the small streams in this sub-basin is very limited. Many small unnamed streams have potential to support cutthroat trout and possibly other salmonids. The cumulative importance of these small streams should be considered. Cataloging of these streams for potential fish presence and habitat should be considered and would help to provide a more complete understanding of fish distribution in this sub-basin.

16.8.4 In-stream Flow

There are no instream flow data gaps in this sub-basin because no significant fish bearing streams have been identified that would warrant instream flow recommendations.

17. INDIAN – MARROWSTONE SUB-BASIN

17.1 BASIN DESCRIPTION

The Indian-Marrowstone Sub-basin is located on two islands, Indian and Marrowstone, which are located between Port Townsend Bay and Admiralty Inlet (Figure 17-1). Killisut Harbor is located between these two islands. No significant freshwater features were identified in this sub-basin.

17.1.1 Surface Water Features

With the exception of marine waters, there are no notable surface water features in this sub-basin.

17.1.2 Groundwater Features

Hydrogeologic characterization of the Indian-Marrowstone sub-basin includes existing maps of surficial geology, generalized geologic cross sections (PGG and EES 1994; Grimstad and Carson 1981) and a fairly extensive hydrogeologic characterization of Marrowstone Island by Department of Ecology (Sinclair and Garrigues 1994). The Ecology study was geared towards assessing saltwater intrusion and provides detailed documentation of most aspects of the island's hydrogeology. Depths to groundwater were measured but lack of surveyed wellhead elevations make interpretation of groundwater elevations potentially misleading. The sub-basin is characterized by extensive areas covered with dense basal till overlying glacial sediments and bedrock of volcanic and sedimentary origin. Bedrock is exposed on the southern end of Indian Island and along various coastal locations on Marrowstone Island such as south of Mystery Bay. On Marrowstone Island, the till overlies Vashon advance outwash sediments in most locations. However, in a few locations the till immediately overlies bedrock. On the southern end of Marrowstone Island, outwash deposits reach thicknesses as great as 100 feet but are thin or absent in places. On the northern end of the island, glacial deposits reach thicknesses as great as 1,400 feet. Wells obtain water from both bedrock and glacial materials, with the glacial materials generally comprising the more productive aquifers (Sinclair and Garrigues 1994). Few wells are completed on Indian Island because the Naval installation gets its water from the Port Townsend water system.

17.1.3 Land Use

Land use on Marrowstone Island is primarily residential and includes farming and forestland Land use on Indian Island is related to the U.S. Navy operations.

The majority of the land use in the Indian-Marrowstone sub-basin is rural residential lands, which comprise approximately 42 percent of the sub-basin with the primary residential land use of one dwelling unit per five acres. Military reservation and parks cover 40 percent and 11 percent, respectively. Existing land use in this sub-basin is shown in Table 17-1.

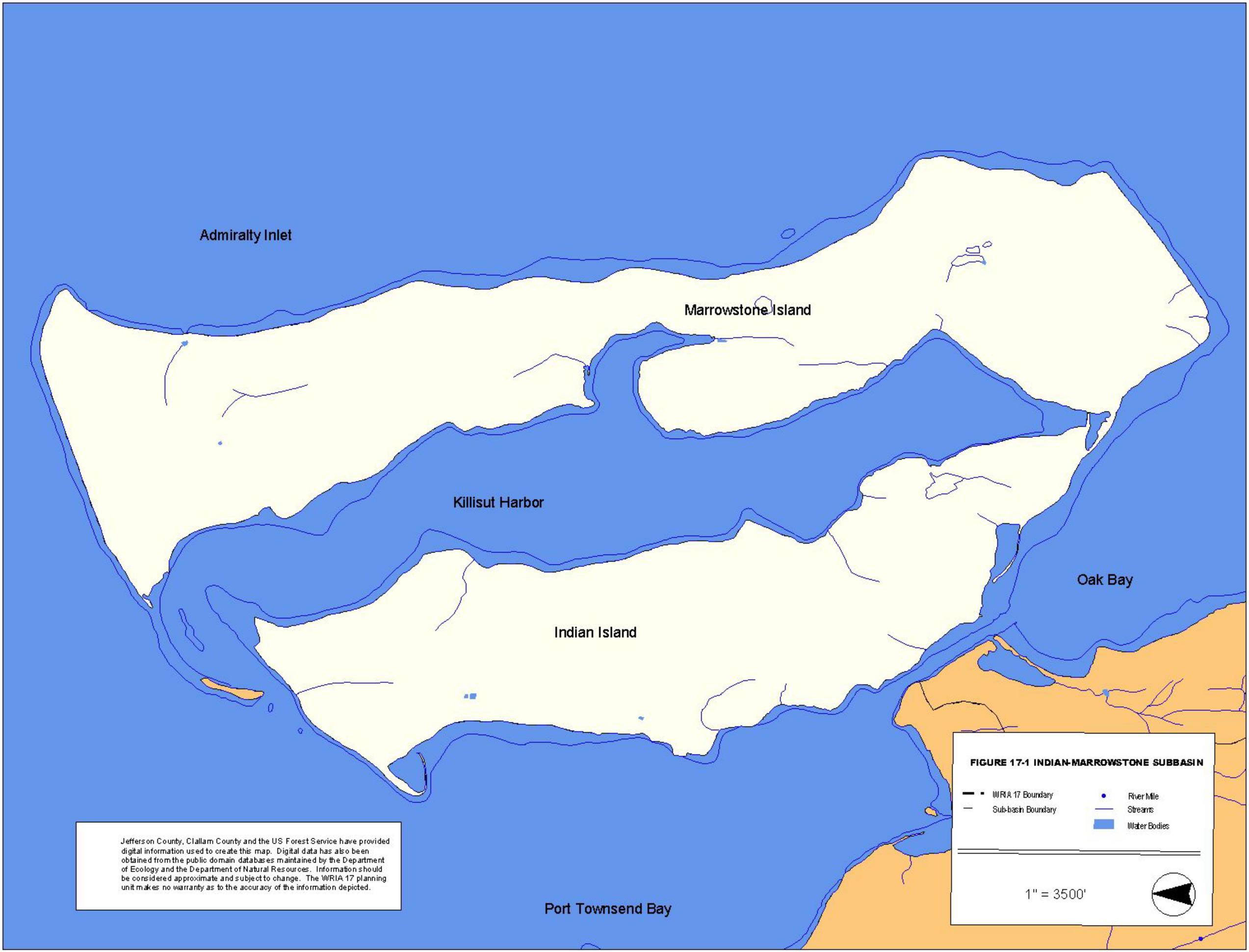

Admiralty Inlet
Marrowstone Island
Killisut Harbor
Oak Bay
Indian Island
Port Townsend Bay
FIGURE 17-1 INDIAN-MARROWSTONE SUBBASIN
WRIA 17 Boundary
Sub-basin Boundary
River Mile
Streams
Water Bodies
1" = 3500'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.

Table 17-1. Indian - Marrowstone Sub-basin Land Use

Description	No. of Parcels	Acres	% of Total
Rural Residential (1:5)	1,014	2,131	31.7%
Rural Residential (1:10)	57	520	7.7%
Rural Residential (1:20)	6	256	3.8%
Parks, Preserves, Recreation	19	768	11.4%
Military Reservations	20	2,726	40.5%
Tidelands	74	187	2.8%
Roads and Right of Ways	78	136	2.0%
Totals	**1,268**	**6,724**	**100.0%**

Source: Jefferson County (2000)

17.2 WATER QUALITY

17.2.1 Surface Water Quality

No water quality monitoring data was available for freshwater features in this sub-basin.

17.2.2 Marine Water Quality

Water Quality in Killisut Harbor is generally considered good. The DOH monitors FC conditions in Killisut Harbor and has approved use of the area for shellfish harvesting. Table 17-2 summarizes the results of DOH data for the period between 1993 and 1998 (DOH 1999a).

Table 17-2. DOH Fecal Coliform Monitoring Results in Killisut Harbor for 1993-1998

Station	No. of Samples	Range	Geometric Mean	Meets Standard
6	30	1.7-17.0	1.9	Yes
7	30	1.7-130.0	2.4	Yes
8	30	1.7-4.5	1.8	Yes
9	30	1.7-95.0	2.2	Yes
10	30	1.7-17.0	1.9	Yes
11	30	1.7-2.0	1.7	Yes
12	30	1.7-7.8	2.0	Yes
14	30	1.7-6.8	1.8	Yes
15	30	1.7-2.0	1.7	Yes
16	29	1.7-31.0	2.1	Yes
17	29	1.7-2.0	1.7	Yes
18	29	1.7-4.5	1.8	Yes
19	29	1.7-4.5	1.9	Yes
20	29	1.7-350.0	2.3	Yes
21	28	1.7-7.8	2.2	Yes

Source: DOH (1999a)

17.2.3 Inventory of Potential Surface Water Contaminant Sources

17.2.3.1 *Point Sources*

Six point sources of pollutants have been identified in this sub-basin based on NPDES permits issued by Ecology. Most of these discharge points are related to the U.S. Naval Base located on Indian Island. Point sources, each with an individual NPDES permit, are summarized below from Ecology (1999a):

- FUDS Fort Flagler
- Fort Flagler State Park Sewer Treatment Plant
- United States Navy Port Hadlock Area 11
- United States Navy Port Hadlock
- United States Navy Port Hadlock Areas 10 and 21
- United States Navy Port Hadlock Area 12

It is noted that NPDES point source locations have been provided by Ecology and in some cases may depict facility names and locations that may not be entirely representative of existing conditions. The Ecology database does also not distinguish between stormwater and/or wastewater permits. No specific monitoring data or compliance problems were available for these specific point sources.

17.2.3.2 *Non-Point Sources*

No non-point sources of pollutants were identified in this sub-basin

17.2.4 Summary of Surface Water Trends and Compliance Problems

No freshwater monitoring data was collected in this sub-basin.

Water quality in Killisut Harbor is generally good. The DOH conducted FC sampling at 15 stations between 1993 and 1998, and no stations exceeded water quality standards for shellfish harvesting or for Class AA marine water bodies.

17.2.5 Groundwater Quality

Chloride concentrations on Marrowstone Island have received attention in the WRIA, due both to a recognized high density of high-chloride wells and an Ecology study on this problem (1994). In contrast, neither chloride nor nitrate data are available from Indian Island, as drinking water on the island is obtained via pipeline from the Tri-Area water system. Chloride concentrations in wells on Marrowstone Island are presented on Exhibit 4. Elevated concentrations occur all around the island, but are less common in inland locations and in the southwestern portion of the island. Data are largely unavailable from the northern portion of the island because Fort Flagler gets its water piped in from the Tri-Area water system.

Ecology's study of saltwater intrusion on Marrowstone Island (Sinclair and Garrigues, 1994) sampled 46 wells with a bias towards coastal locations. The study found that 24 percent of the wells sampled had chloride concentrations in excess of the MCL (250 mg/l) and 46 percent had levels in excess of 100 mg/l. Concentrations were lower in the island interior than on the coast, higher in wells completed below sea level, and higher for wells that received high use. Lower chloride concentrations noted south of Meade Road (southern quarter of island) may be due to the fact that the primary (glacial drift) aquifer lies at elevations above and slightly below sea level. Ecology also noted historically increasing chloride

concentrations in the narrow part of the island east of Mystery Bay. This area is most susceptible to intrusion due to relatively high water use and limited recharge due to the narrowness of the island in this location. Ecology concluded that elevated chloride is a pervasive problem on Marrowstone Island.

Citizens on Marrowstone Island have taken an active role in the concern for, and investigation of, elevated chloride concentrations. Samples have been routinely collected from wells, surface-water bodies, and precipitation and analyzed with field kits; however, these data have not been rigorously evaluated. General agreement about the causes and severity of water-quality degradation on the island is lacking. Although no one denies the elevated chloride concentrations measured in wells, some contest the claim that water quality is being further degraded due to increased saltwater intrusion. It is likely the case that some elevated chloride concentrations are due to wells completed close to the natural zone of diffusion (between fresh and salty groundwater). It is also possible that some elevated concentrations are due to wells completed in lower-permeability aquifer "pockets" with "trapped" or "relict" seawater. However, the occurrence of wells with low background concentrations suggests that the process of "flushing" does occur in portions of the groundwater flow system, and areas with higher coastal concentrations suggest a coastal source of chloride. In those areas where a dynamic balance exists between fresh and salty groundwater, increased pumping will shift the saltwater wedge toward the pumping source. The severity of such saltwater intrusion will vary based on specific hydrogeologic conditions of the site. As for any coastal area showing clustered occurrence of elevated chloride concentrations, caution is warranted when considering increased groundwater withdrawals from affected areas of Marrowstone Island.

Nitrate-nitrogen concentrations on Marrowstone Island are mapped on Exhibit 5. The majority of nitrate-nitrogen concentrations reflect background ("natural") concentrations. Two cases of nitrate concentrations ranging from 5 to10 mg/l are found on the island. A local cluster, comprised of nitrate concentrations ranging from 1 to 5 mg/l is noted near East Beach Park (east of Mystery Bay), and several other isolated cases of mildly elevated nitrate-nitrogen concentrations (1 to 2 mg/l) are noted in Marrowstone Island wells.

Groundwater contamination due to a leaking underground storage tank was discovered in Nordland, but the site is reported cleaned up with ongoing monitoring. Groundwater contamination is reported at three sites at the naval facility on Indian Island but does not impact drinking water quality due to the external source of supply.

17.3 WATER QUANTITY

17.3.1 Groundwater Use and Allocation

Exhibit 11 shows the spatial distribution of groundwater use in the Indian-Marrowstone sub-basin. The total groundwater withdrawal, assuming a domestic use of 250 gpd, is 287 af/yr. Approximately 64 percent of this total use is estimated from water rights and claims for irrigation purposes, and is qualified as being "lower accuracy" data. The remaining 36 percent (104 af/yr) is based on various sources for domestic and commercial uses, and is believed to be relatively high quality data. In addition, groundwater from the Tri-Area water system is used as a source of supply for Fort Flagler (Marrowstone Island) and the naval base on Indian Island. On Marrowstone Island, the general reliance on septic systems in the sub-basin dictates that the consumptive portion of domestic and commercial withdrawals is likely to be much lower than the total amount withdrawn. Indian Island has a wastewater treatment facility that treats wastewater for all residences and facilities on the Island and sends treated wastewater to the bay. Some of the water provided by the City is used to replenish visiting ships.

In the Indian-Marrowstone sub-basin, 11 groundwater rights have been issued for a total of 42 af/yr. The spatial distribution of groundwater rights is presented in Exhibit 8. Figure 17-2 presents a pie chart of groundwater rights by use that shows approximately 53 percent of the total allocation is for domestic uses and 47 percent is for irrigation.

There are 361 well logs registered for the Indian-Marrowstone sub-basin, translating to a potential exempt allocation of 2,022 af/yr. More unregistered wells are likely to exist, however only a small portion of this exempt allocation is likely to be actually put to use.

There are 207 groundwater claims in the sub-basin. Table 4-2 lists claims by use, and shows that 48 of these claims list irrigation as a principal use. Typically, only a portion of claims listing irrigation as a purpose-of-use list numbers of irrigated acres. In the Indian-Marrowstone sub-basin, water use associated with the reported numbers of irrigated acres amounts to 164 af/yr. If each claim is also assumed to include a domestic use, total claimed groundwater can be estimated at about 371 af/yr. The portion of these claims that have been actually put to use, and would qualify for a water right, is unknown. A map of the distribution of groundwater claims is presented on Exhibit 9.

There are no water right applications pending for the Indian-Marrowstone sub-basin.

17.3.2 Surface Water Use and Allocation

There are no surface water rights for the Indian/Marrowstone sub-basin. The sub-basin does maintain a claim however, of 0.08 cfs with an annual quantity estimated at 8 af/yr.

17.3.3 Hydraulic Continuity Potential

There are no major streams mapped in the Indian-Marrowstone sub-basin. Relative hydraulic continuity potential was not evaluated.

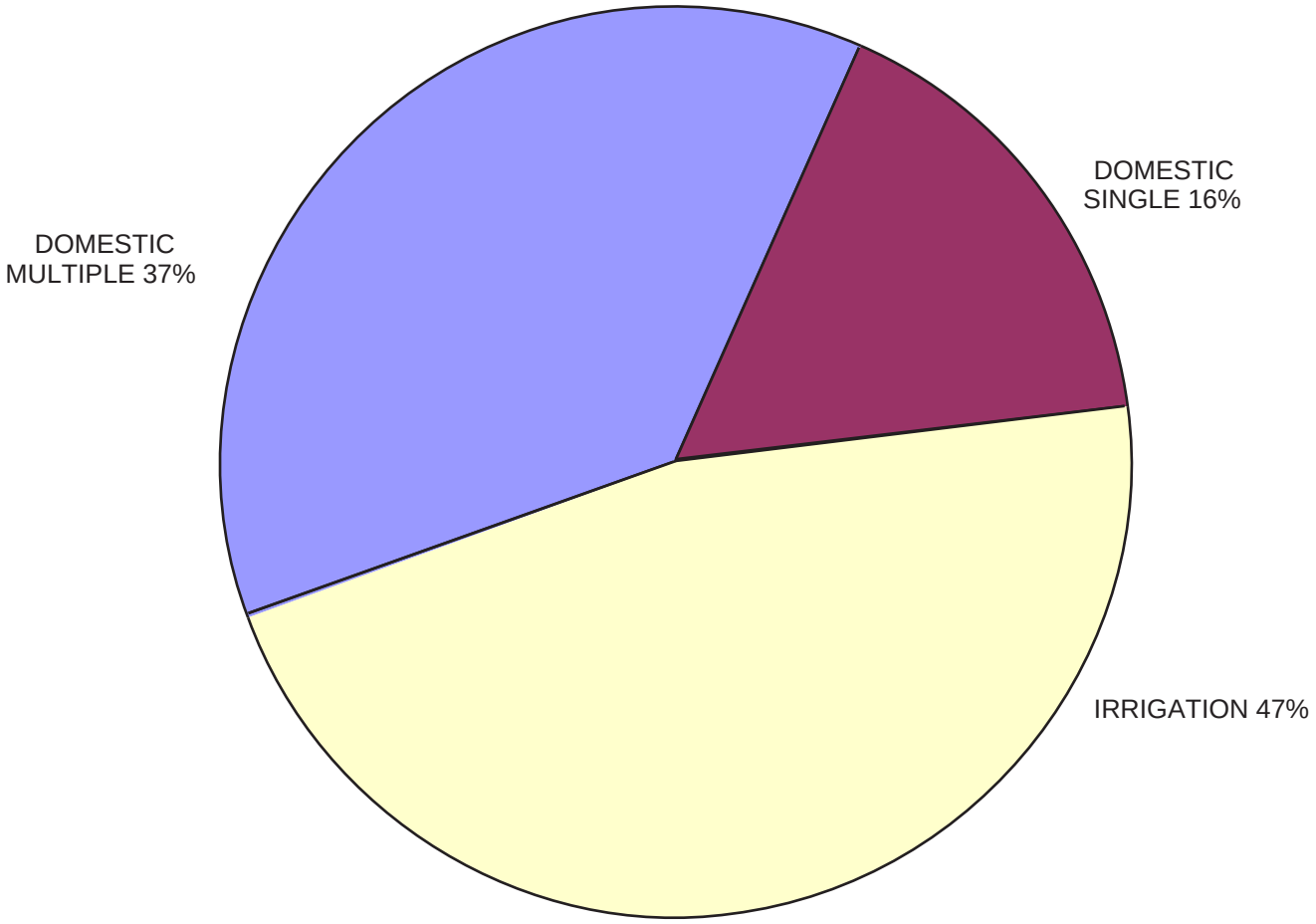
17.4 HABITAT

Salmonid fish distribution and habitat quality are not described for the Indian - Marrowstone sub-basin. Streams that support anadromous salmonids are not known to exist in this area, though the extensive shallow shorelines and embayments around Indian and Marrowstone islands provide important migrational and rearing corridors for these species.

17.5 INSTREAM FLOW

No instream flow studies were found for this sub-basin.

GROUNDWATER RIGHTS (QA) BY USE



Note: total allocation = 42 af/yr, accounted by use = 42 af/yr, domestic calculated from well logs = 1451 af/yr

Source: Ecology WRATs database

Figure 17-2
Indian-Marrowstone Sub-Basin Groundwater and Surface Water Rights and Use, Consumptive Use Only

17.6 FUTURE PROJECTIONS AND POTENTIAL IMPACTS

17.6.1 Potential Effects of Land Use Variation on Groundwater and Surface Water Quantity

The data available to characterize future changes in land use in the Indian-Marrowstone sub-basin are generally limited to estimates of population growth. Table 17-1 shows that agricultural and commercial forest zoning is insignificant in the sub-basin. Population projections and zoning patterns can be used to qualitatively predict changes in patterns of residential and associated commercial land use. Increased population requires increased paved surfaces for homes, driveways, roads, and commercial infrastructure. Population increases are expected to occur in areas zoned as rural residential. As indicated in Chapter 4, little direct data are available regarding the effects of paving on groundwater recharge at typical rural residential densities. While the effects of increased paving in rural residential areas are not expected to be substantial, some reduction in recharge may be associated with conversion of forested lands to meadows and lawns. The effect of population increase on groundwater and surface water withdrawals is presented in Section 17.6.3.

17.6.2 Population Growth

In 1996, the Indian-Marrowstone sub-basin had 893 residents (Jefferson County 2000). Indian-Marrowstone sub-basin population growth over the next 20 years is estimated at 176 residents (Jefferson County 1998). Based on existing zoning (refer to Exhibit 1), the population growth will most likely occur along the shoreline and southern two-thirds of Marrowstone Island.

17.6.3 Potential Impacts of Growth on Water Demand

Population in the Indian-Marrowstone sub-basin is expected to increase by 21 percent between 1996 and 2016. Assuming that an average residence contains 2.2 people and uses 250 gpd, the projected increase of 176 people will cause an increased water demand of approximately 22 af/yr. Groundwater is currently the principal source of residential supply for most of the sub-basin, and is predominantly withdrawn by single family domestic wells. Additional demand will likely be satisfied by similar sources. If additional demand is met with the groundwater resource, estimated current groundwater withdrawals (287 af/yr for residential, commercial and agricultural purposes) would increase by about 8 percent. The increased demand also represents about 0.7 percent of estimated groundwater recharge, with current groundwater withdrawals estimated at 9.5 percent. However, as discussed in Chapter 4, comparison of groundwater pumping with recharge cannot be reliably used as a direct indicator of groundwater availability.

Given the rural nature of the sub-basin, residential reliance on septic systems dictates that the consumptive portion of residential use is significantly less than the total residential groundwater withdrawal. Assuming that 87 percent of residential withdrawals are returned to the ground via septic infiltration (Solly et al. 1993), the actual increase in groundwater consumption would be on the order of 3 af/yr.

17.6.4 Potential Impacts of Land Use and Growth on Habitat

Prediction of impacts to habitat due to population growth are hampered by lack of data on existing habitat and salmonid use in this sub-basin. However, given that some growth is expected in this sub-basin, potential impacts may occur on estuarine and near shore marine habitat through bulkheads, clearing of vegetation and erosion.

17.6.5 Conservation Options for the Indian-Marrowstone Sub-basin

Water conservation options that may be applicable to water users in the Indian-Marrowstone Sub-basin are summarized below.

- Tiered Water Rate Structures
- Modification of Landscape Irrigation Practices
- Water Conservation in Water Supply Systems and Individual Homes
- Educational programs
- Water Conservancy Boards To Facilitate Water Rights Transfers

17.7 DATA SYNTHESIS AND INTEGRATION

Existing data for this sub-basin is limited primarily to groundwater quality. Refer to section 16.2 for discussion of groundwater quality issues in this sub-basin. Water use in this sub-basin is typically below 6-ac/ft/year on a section basis, with water use representing approximately 9.5 percent of estimated recharge.

17.8 DATA QUALITY, GAPS AND LIMITATIONS

In addition to the general data gaps identified for the entire WRIA, the following specific data gaps have been identified for this sub-basin :

17.8.1 Water Quality

Data quality and quantity limitations in this sub-basin are consistent with those discussed for the entire WRIA. General data quantity and quality limitations are as follows:

- Ambient water quality conditions for parameters other than FC are not available.

- Available FC data is limited temporally, which limits the ability to detect trends.

- No data available for pollutants in the effluent of NPDES discharge locations; limits the ability to assess pollutant loading at these locations.

17.8.2 Water Quantity

Water quantity data gaps have been identified for the entire WRIA and generally apply to the Indian-Marrowstone sub-basin. The following additional definition of data gaps is based on consideration of currently existing data, and provides additional detail where possible:

- The hydrogeology of Marrowstone Island has been fairly well characterized by Department of Ecology (Sinclair and Garrigues 1994). However, groundwater elevations were not available for use in evaluation of saltwater intrusion. An elevation survey of wells monitored for chloride may improve understanding of saltwater intrusion conditions.

- Given the level of existing hydrogeologic characterization, additional characterization would likely focus on gaining a better understanding of local variations in aquifer properties and the relationship between pumping, groundwater levels, and saltwater intrusion.

17.8.3 Habitat

Data on fish habitat for the small streams in this sub-basin is very limited. Many small unnamed streams have potential to support cutthroat trout and possibly other salmonids. The cumulative importance of these small streams should be considered. Cataloging of these streams for potential fish presence and habitat should be considered and would help to provide a more complete understanding of fish distribution in this sub-basin.

17.8.4 In-stream Flow

There are no instream flow data gaps in this sub-basin because no significant fish bearing streams have been identified that would warrant instream flow recommendations.

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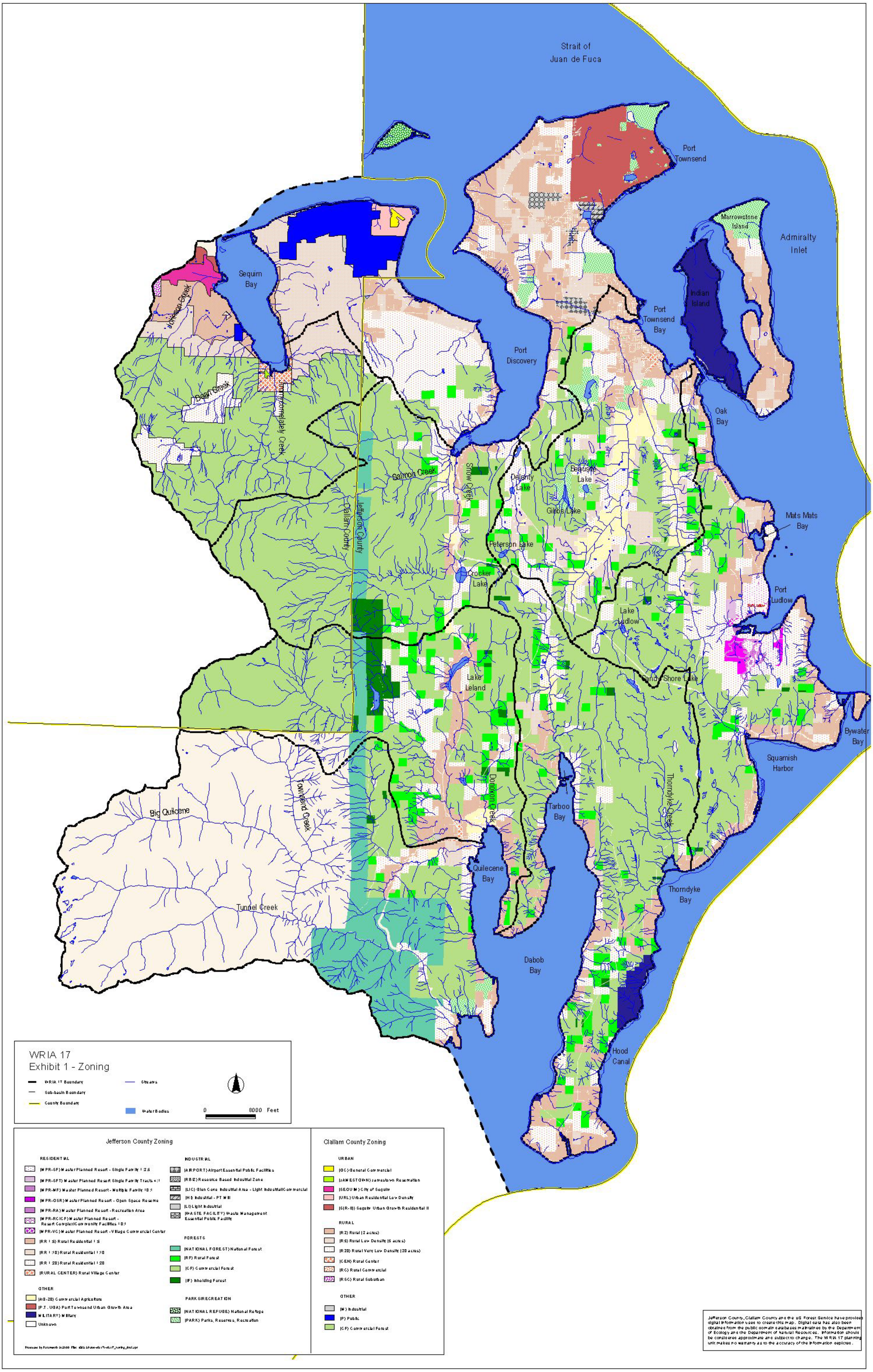
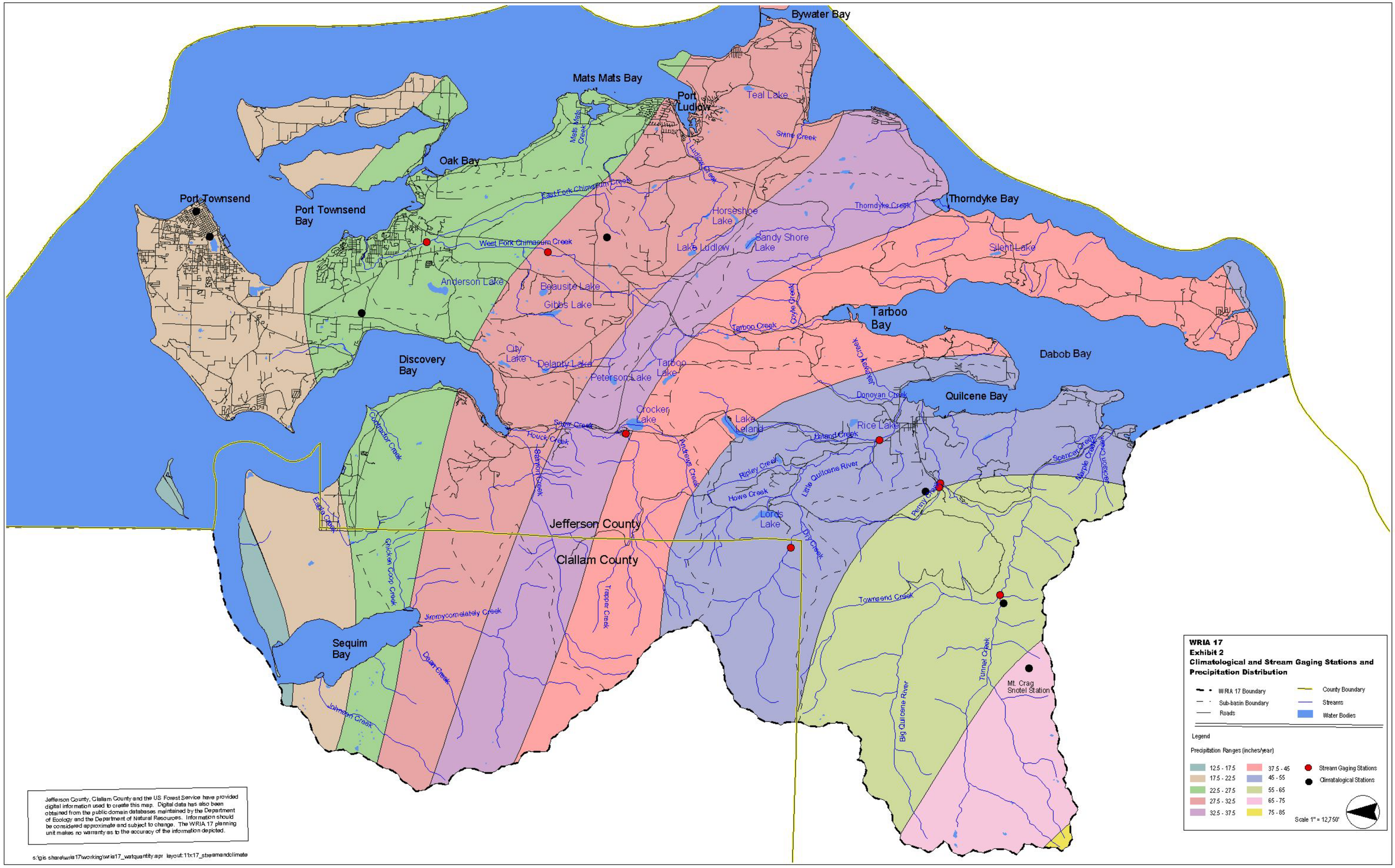
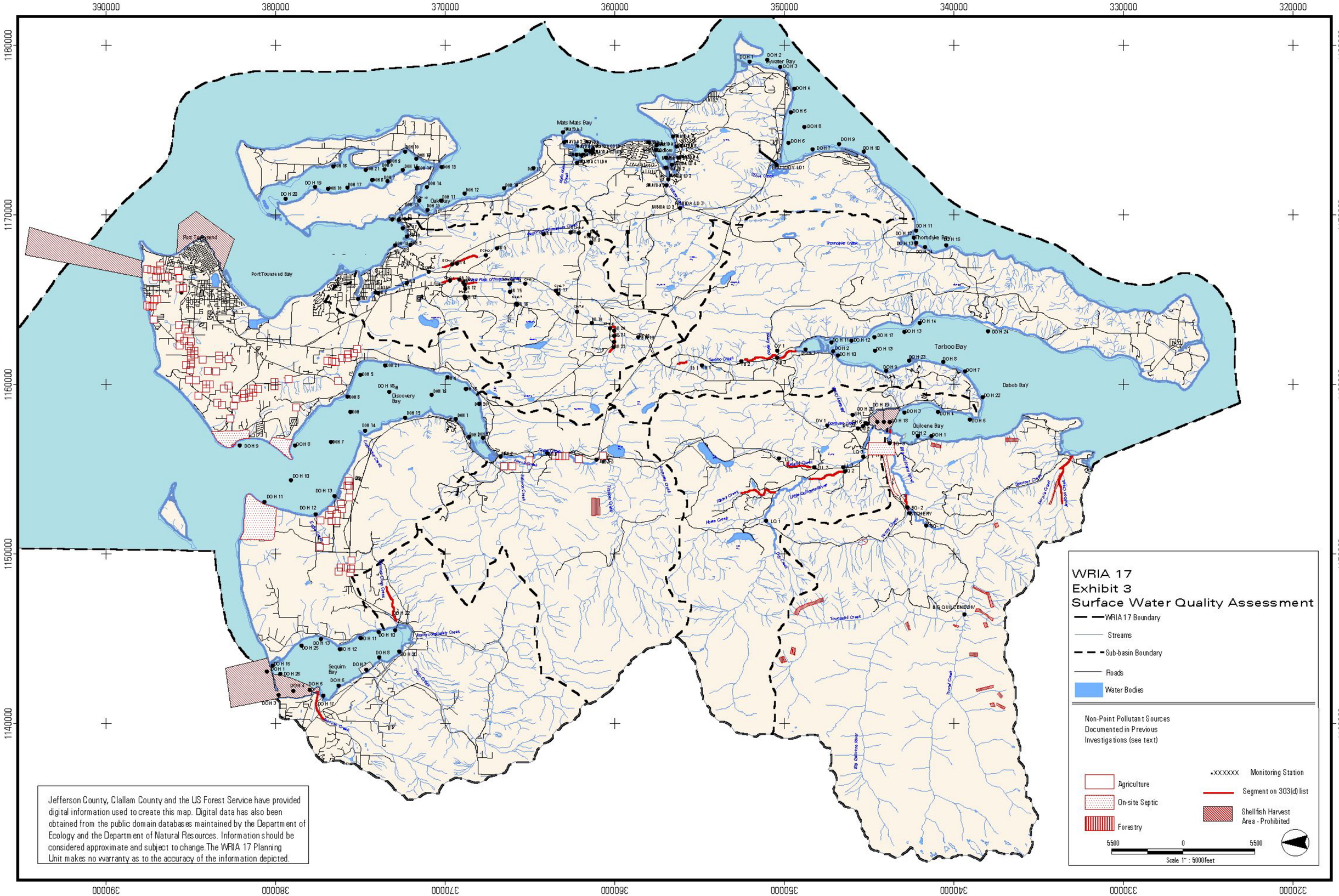
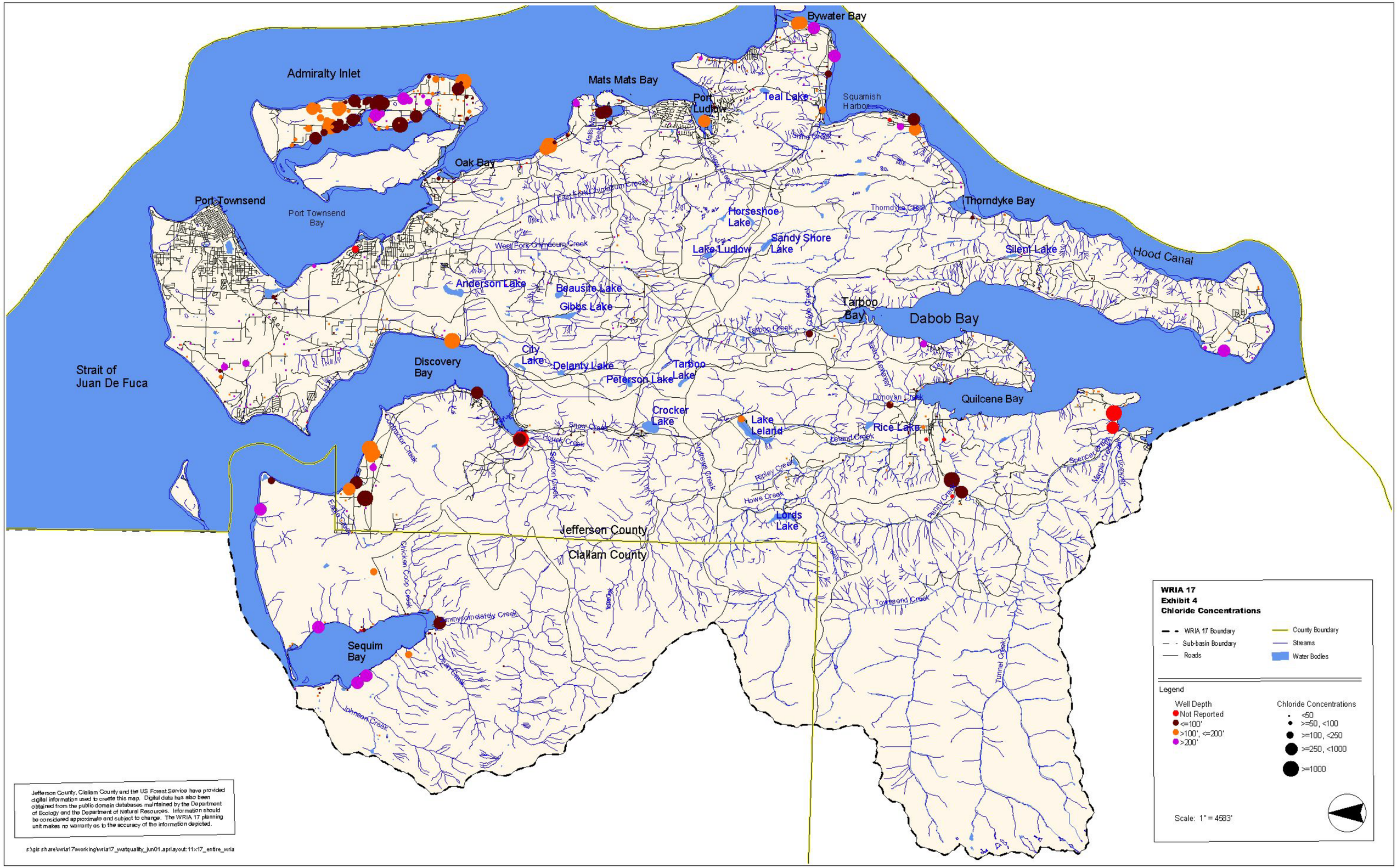
APPENDIX A

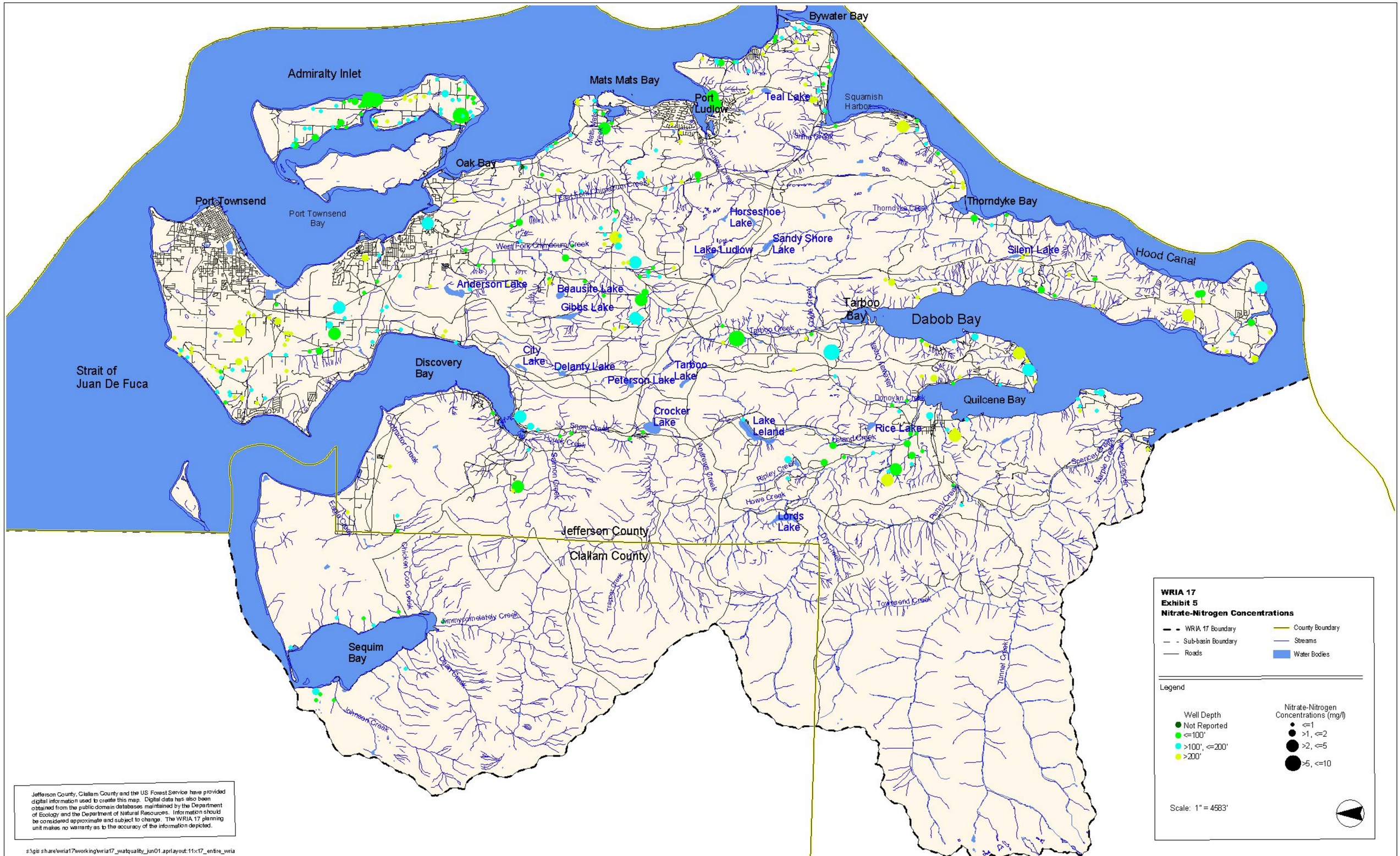
GIS EXHIBITS

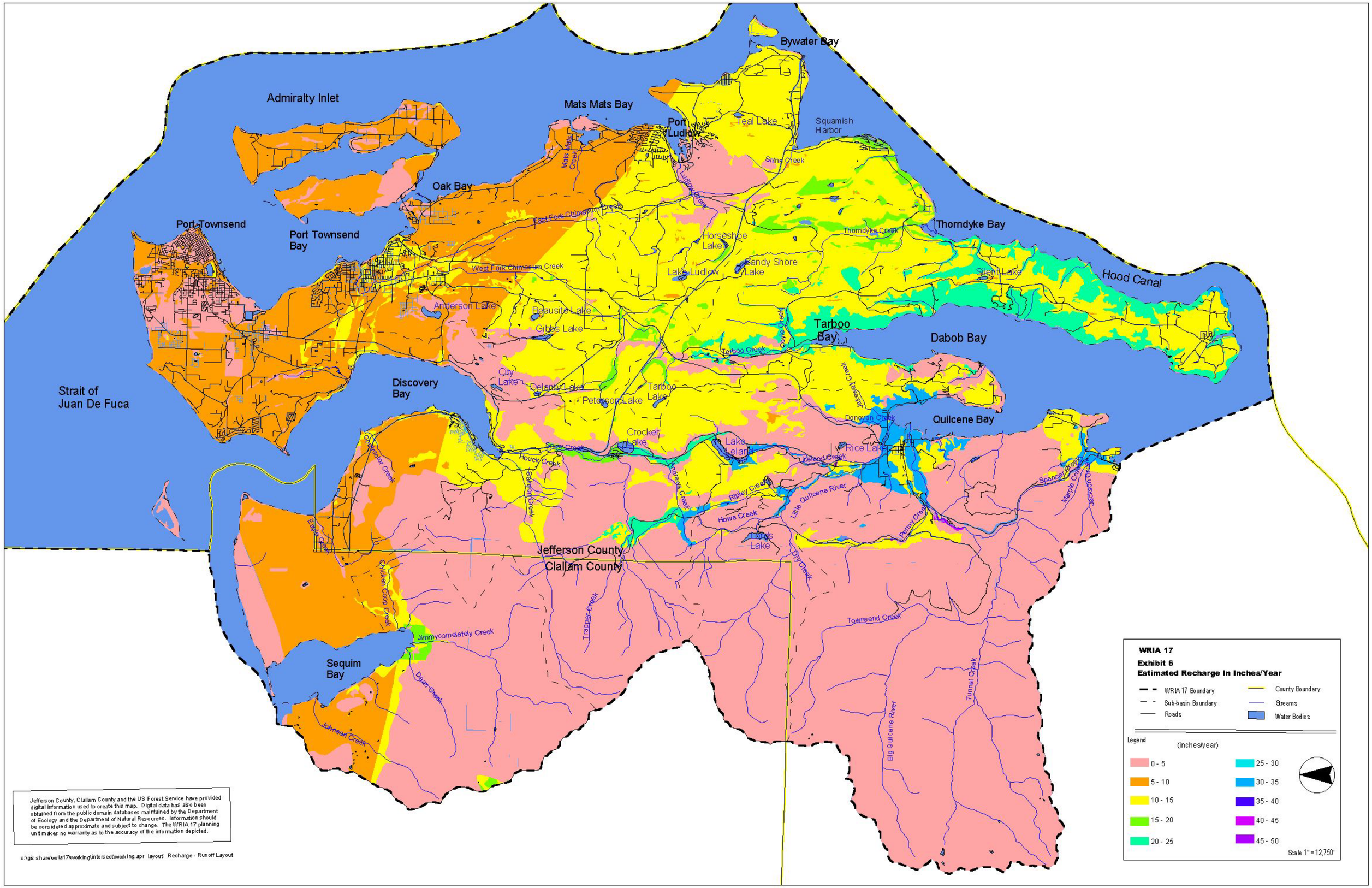

Strait of
Juan de Fuca
Port
Townsend
Marrowstone
Island
Admiralty
Inlet
Sequim
Bay
Johnson Creek
Indian
Island
Port
Townsend
Bay
Port
Discovery
Dean Creek
Chimacum Creek
Oak
Bay
Salmon Creek
Snow Creek
Delanty
Lake
Beausite
Lake
Gibbs Lake
Mats Mats
Bay
Clallam County
Jefferson County
Peterson Lake
Crocker
Lake
Port
Ludlow
Lake
Ludlow
Lake
Leland
Sandy Shore Lake
Bywater
Bay
Squamish
Harbor
Big Quilcene
Townsend Creek
Dosewallips Creek
Tarboo
Bay
Thorndyke Creek
Quilcene
Bay
Thorndyke
Bay
Tunnel Creek
Dabob
Bay
Hood
Canal
WRIA 17
Exhibit 1 - Zoning
WRIA 17 Boundary
Sub-basin Boundary
County Boundary
Streams
Water Bodies
0
8000 Feet
Jefferson County Zoning
RESIDENTIAL
(MPR-SF) Master Planned Resort - Single Family 1:2.5
(MPR-SFT) Master Planned Resort Single Family Tracts 4:1
(MPR-MF) Master Planned Resort - Multiple Family 10:1
(MPR-OSR) Master Planned Resort - Open Space Reserve
(MPR-RA) Master Planned Resort - Recreation Area
(MPR-RC/CF) Master Planned Resort - Resort Complex/Community Facilities 10:1
(MPR-VC) Master Planned Resort - Village Commercial Center
(RR 1:5) Rural Residential 1:5
(RR 1:10) Rural Residential 1:10
(RR 1:20) Rural Residential 1:20
(RURAL CENTER) Rural Village Center
OTHER
(AG-20) Commercial Agriculture
(P.T. UGA) Port Townsend Urban Growth Area
MILITARY) Military
Unknown
INDUSTRIAL
(AIRPORT) Airport Essential Public Facilities
(RBIZ) Resource Based Industrial Zone
(LIC) Glen Cove Industrial Area - Light Industrial/Commercial
(H) Industrial - PT Mill
(LI) Light Industrial
(WASTE FACILITY) Waste Management Essential Public Facility
FORESTS
(NATIONAL FOREST) National Forest
(RF) Rural Forest
(CF) Commercial Forest
(IF) Inholding Forest
PARKS/RECREATION
(NATIONAL REFUGE) National Refuge
(PARK) Parks, Reserves, Recreation
Clallam County Zoning
URBAN
(GC) General Commercial
(JAMESTOWN) Jamestown Reservation
(SEQUIM) City of Sequim
(URL) Urban Residential Low Density
(SIR-II) Sequim Urban Growth Residential II
RURAL
(R2) Rural (2 acres)
(R5) Rural Low Density (5 acres)
(R20) Rural Very Low Density (20 acres)
(CEN) Rural Center
(RC) Rural Commercial
(RSC) Rural Suburban
OTHER
(M) Industrial
(P) Public
(CF) Commercial Forest
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.

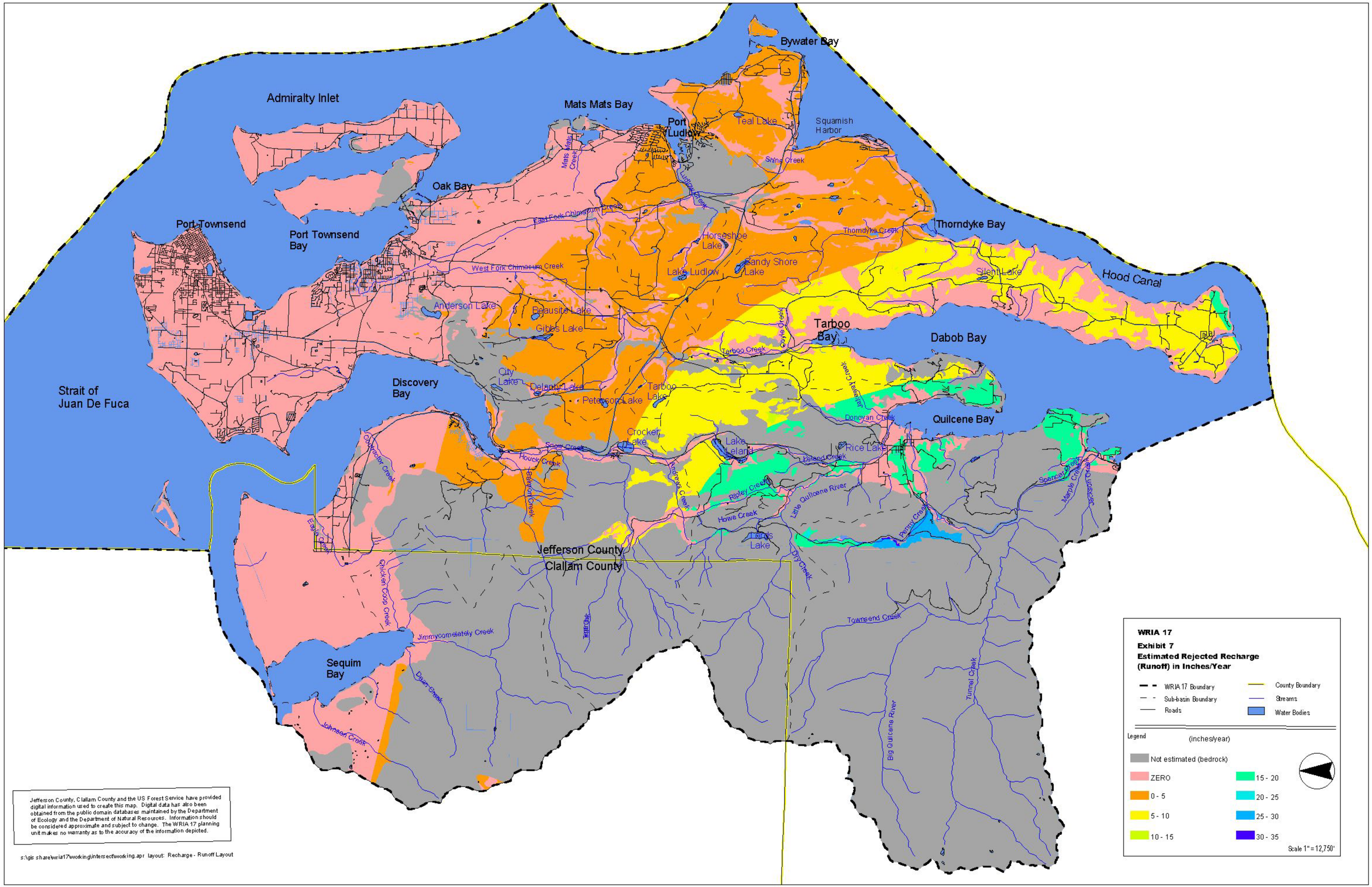

Bywater Bay
Mats Mats Bay
Port Ludlow
Teal Lake
Shine Creek
Mats Mats Creek
Ludlow Creek
Oak Bay
East Fork Chimacum Creek
Port Townsend
Port Townsend Bay
Thorndyke Bay
Thorndyke Creek
Horseshoe Lake
Sandy Shore Lake
Lake Ludlow
West Fork Chimacum Creek
Silent Lake
Anderson Lake
Beausite Lake
Gibbs Lake
Coyle Creek
Tarboo Bay
Tarboo Creek
Dabob Bay
City Lake
Delanty Lake
Tarboo Lake
Peterson Lake
Hamma Hamma Creek
Donovan Creek
Quilcene Bay
Discovery Bay
Crocker Lake
Lake Leland
Rice Lake
Leland Creek
Spring Creek
Houck Creek
Contractor Creek
Salmon Creek
Andrews Creek
Ripley Creek
Little Quilcene River
Spencer Creek
Hamle Creek
Jackson Creek
Howe Creek
Lords Lake
Penny Creek
Dry Creek
Eagle Creek
Jefferson County
Clallam County
Chicken Coop Creek
Trapper Creek
Townsend Creek
Jimmycomelately Creek
Sequim Bay
Dean Creek
Tunnel Creek
Mt. Crag Snotel Station
Big Quilcene River
Johnson Creek
WRIA 17
Exhibit 2
Climatological and Stream Gaging Stations and Precipitation Distribution
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend
Precipitation Ranges (inches/year)
12.5 - 17.5
17.5 - 22.5
22.5 - 27.5
27.5 - 32.5
32.5 - 37.5
37.5 - 45
45 - 55
55 - 65
65 - 75
75 - 85
Stream Gaging Stations
Climatological Stations
Scale 1" = 12,750'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\wria17_watquantity.apr layout:11x17_streamandclimate

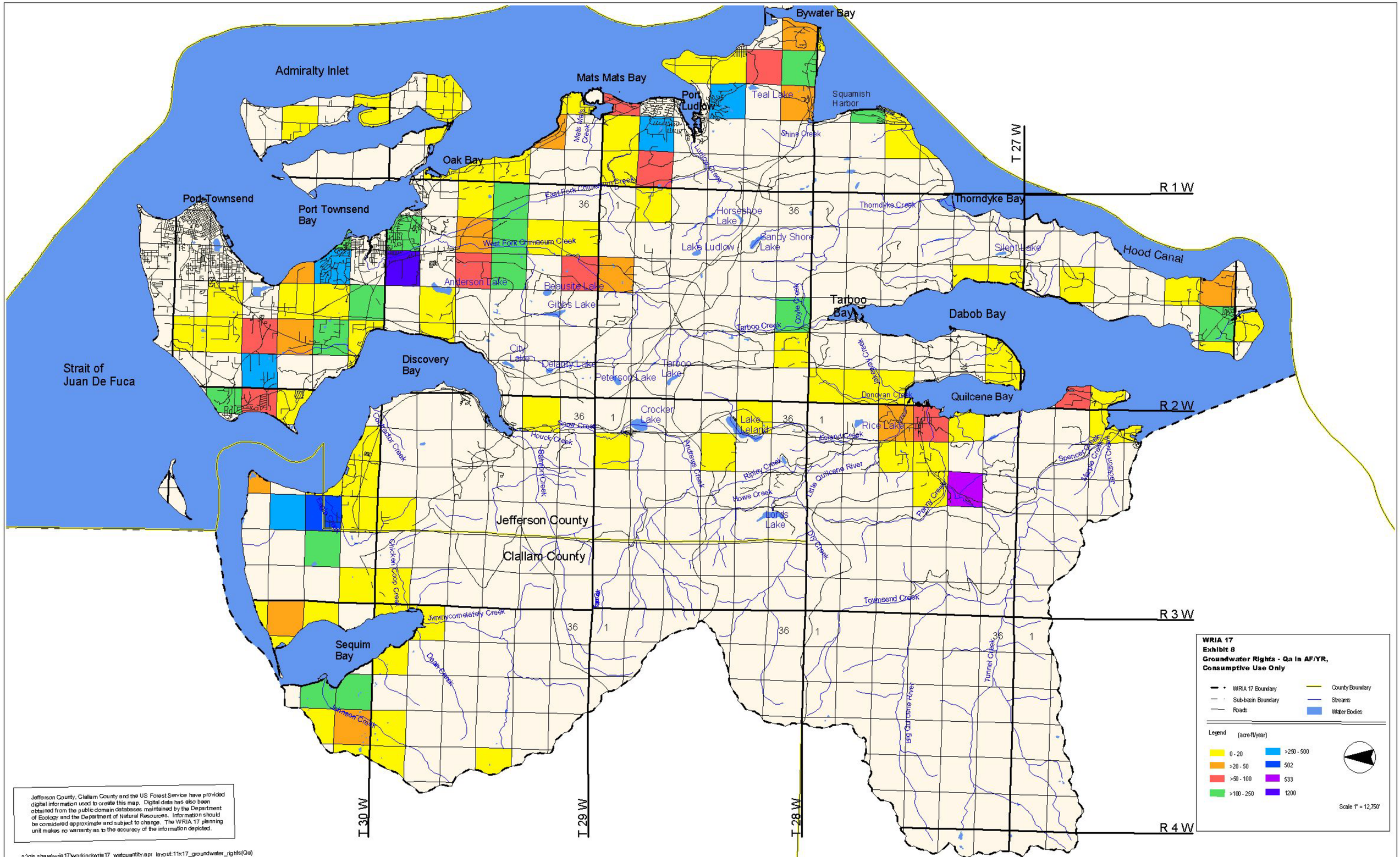

WRIA 17
Exhibit 3
Surface Water Quality Assessment
WRIA 17 Boundary
Streams
Sub-basin Boundary
Roads
Water Bodies
Non-Point Pollutant Sources Documented in Previous Investigations (see text)
Agriculture
On-site Septic
Forestry
Monitoring Station
Segment on 303(d) list
Shellfish Harvest Area - Prohibited
5500 0 5500
Scale 1" : 5000feet
Port Townsend
Port Townsend Bay
Mats Mats Bay
Oak Bay
Discovery Bay
Sequim Bay
Tarboo Bay
Dabob Bay
Quilcene Bay
Thorndyke Bay
Big Quilcene River
Little Quilcene River
Tarboo Creek
Townsend Creek
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 Planning Unit makes no warranty as to the accuracy of the information depicted.

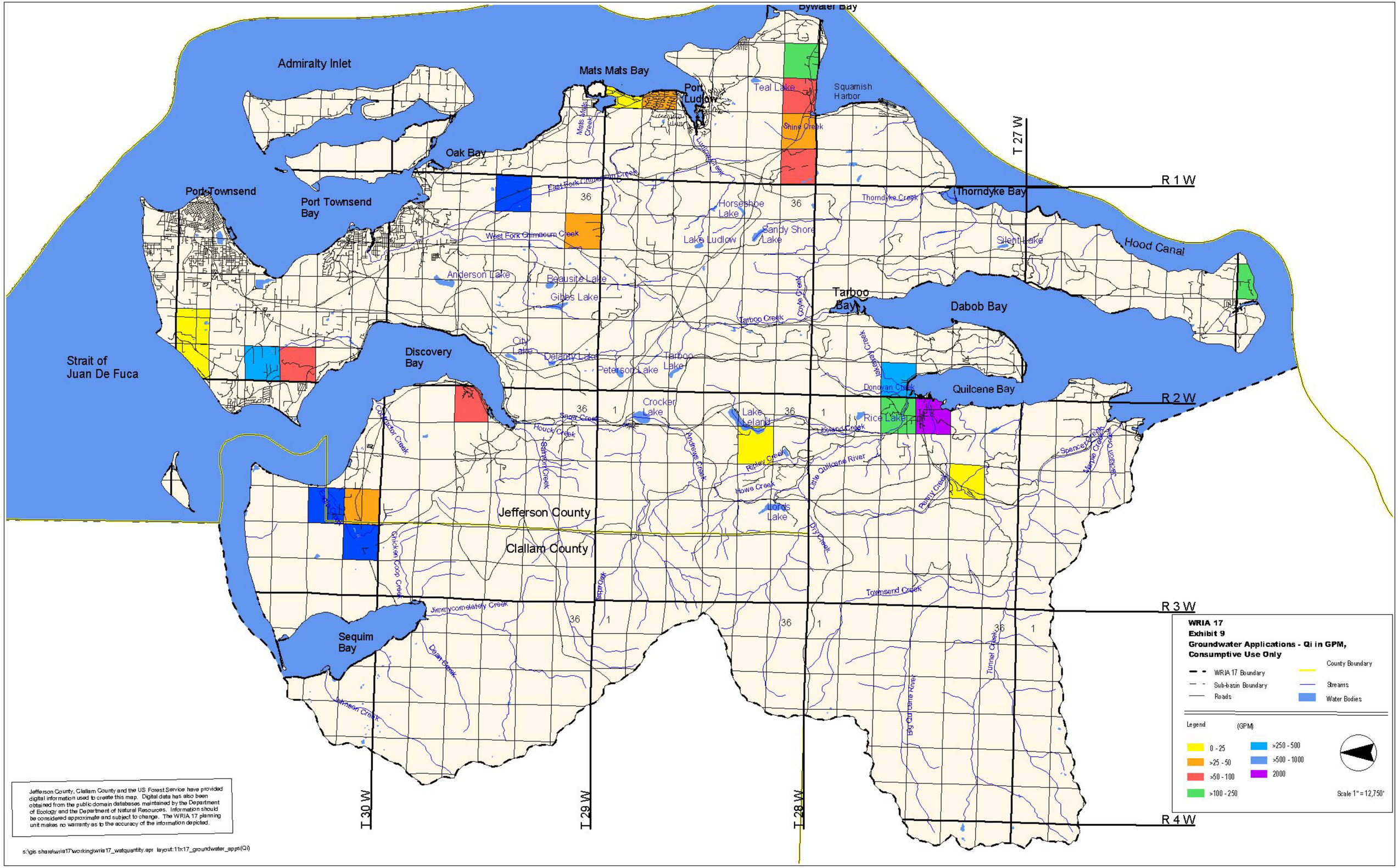

Bywater Bay
Admiralty Inlet
Mats Mats Bay
Port Ludlow
Teal Lake
Squamish Harbor
Oak Bay
Port Townsend
Port Townsend Bay
Thorndyke Bay
Horseshoe Lake
Sandy Shore Lake
Lake Ludlow
Silent Lake
Hood Canal
Anderson Lake
Beausite Lake
Gibbs Lake
Tarboo Bay
Dabob Bay
Strait of Juan De Fuca
Discovery Bay
City Lake
Delanty Lake
Peterson Lake
Tarboo Lake
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Lords Lake
Jefferson County
Clallam County
Sequim Bay
WRIA 17
Exhibit 4
Chloride Concentrations
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend
Well Depth
Not Reported
<=100'
>100', <=200'
>200'
Chloride Concentrations
<50
>=50, <100
>=100, <250
>=250, <1000
>=1000
Scale: 1" = 4583'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\wria17_watquality_jun01.aprlayout:11x17_entire_wria

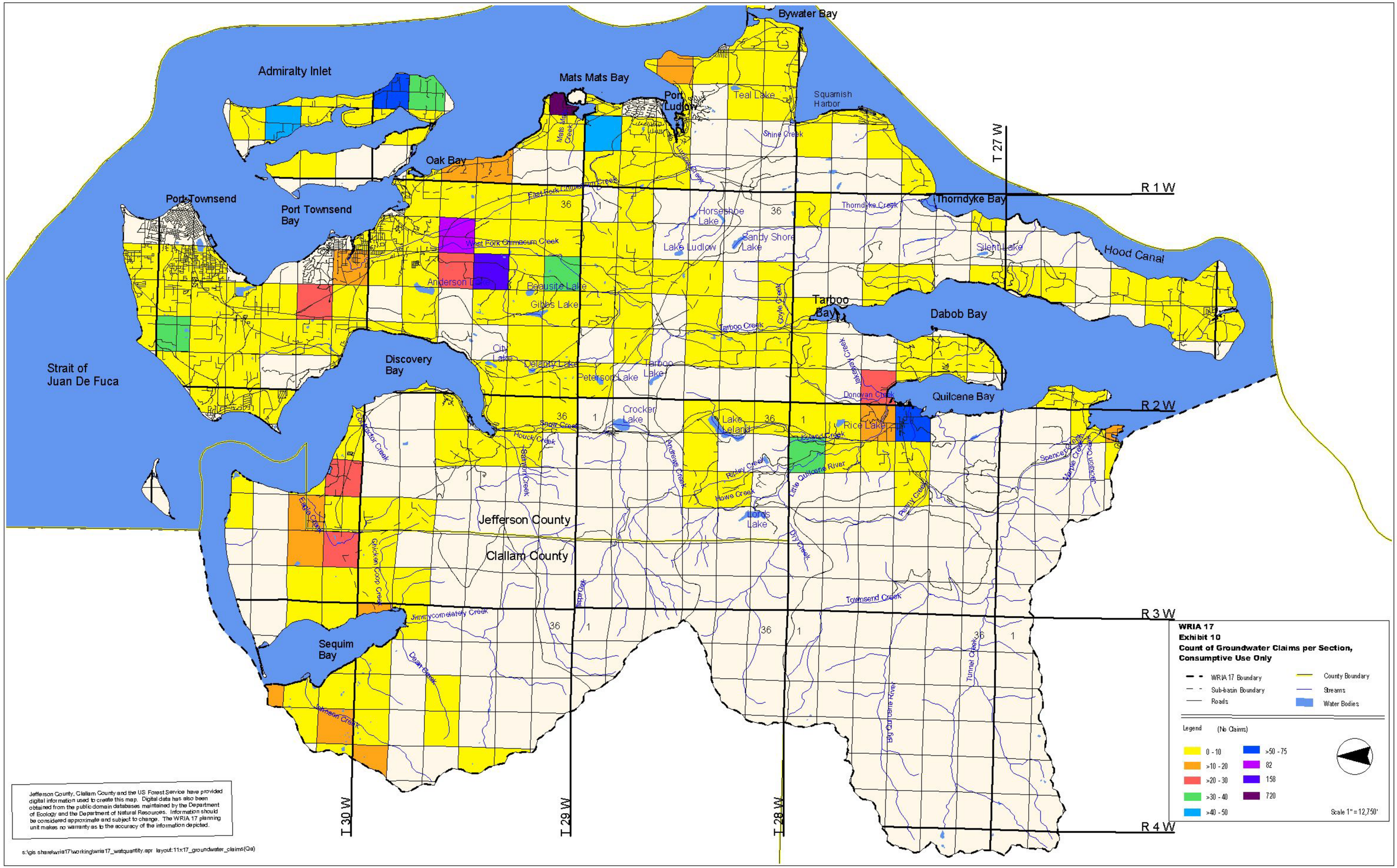

Bywater Bay
Admiralty Inlet
Mats Mats Bay
Port Ludlow
Teal Lake
Squamish Harbor
Oak Bay
Port Townsend
Port Townsend Bay
Thorndyke Bay
Horseshoe Lake
Sandy Shore Lake
Lake Ludlow
Silent Lake
Hood Canal
Anderson Lake
Beausite Lake
Gibbs Lake
Tarboo Bay
Dabob Bay
Strait of Juan De Fuca
Discovery Bay
City Lake
Delanty Lake
Peterson Lake
Tarboo Lake
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Lords Lake
Jefferson County
Clallam County
Sequim Bay
WRIA 17
Exhibit 5
Nitrate-Nitrogen Concentrations
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend
Well Depth
Not Reported
<=100'
>100', <=200'
>200'
Nitrate-Nitrogen Concentrations (mg/l)
<=1
>1, <=2
>2, <=5
>5, <=10
Scale: 1" = 4583'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\wria17_watquality_jun01.aprlayout:11x17_entire_wria

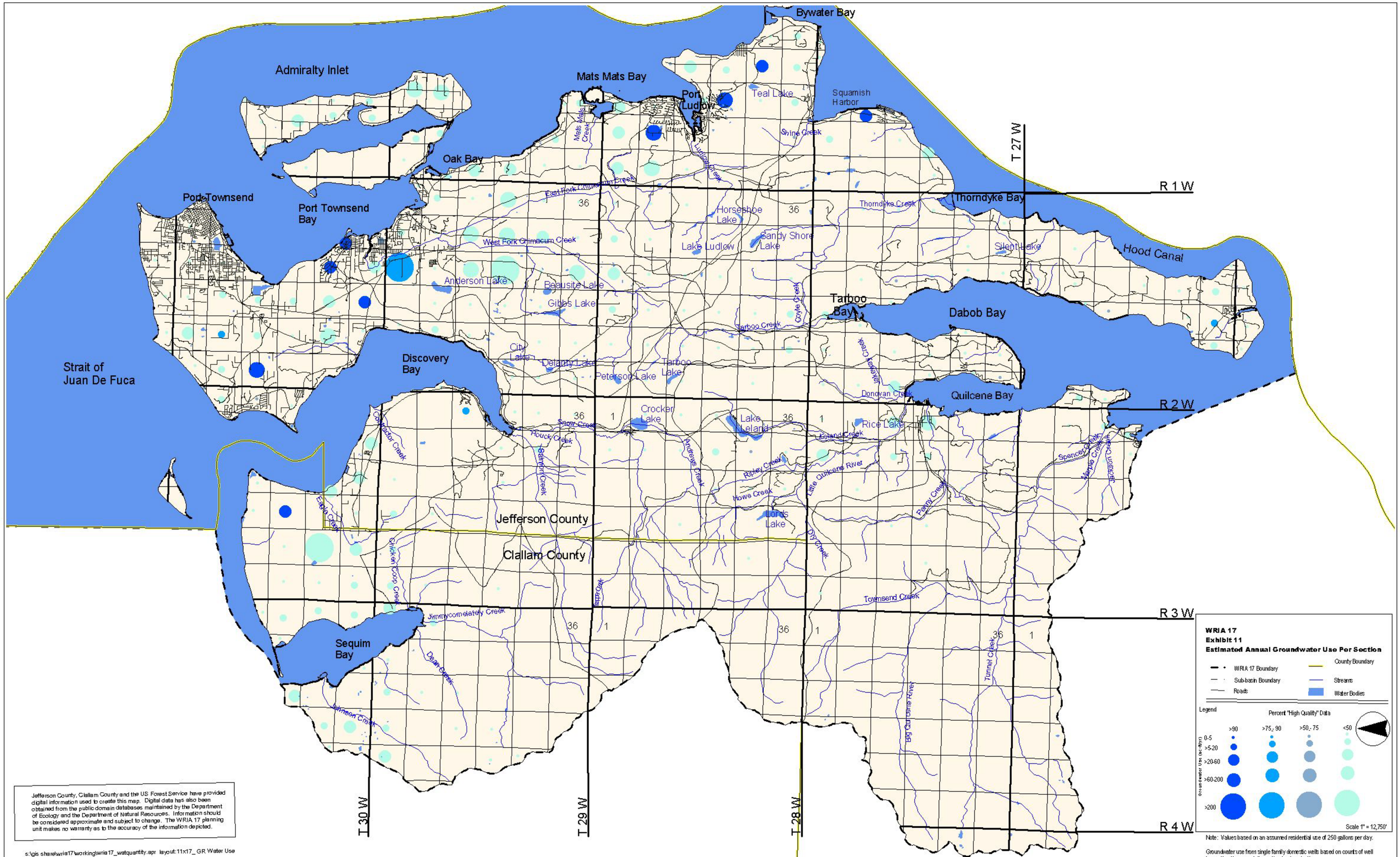

Bywater Bay
Admiralty Inlet
Mats Mats Bay
Port Ludlow
Teal Lake
Squamish Harbor
Shine Creek
Oak Bay
Port Townsend
Port Townsend Bay
East Fork Chimacum Creek
Thorndyke Bay
Thorndyke Creek
Horseshoe Lake
Sandy Shore Lake
Lake Ludlow
West Fork Chimacum Creek
Silent Lake
Hood Canal
Anderson Lake
Belausite Lake
Gibbs Lake
Tarboo Bay
Dabob Bay
Tarboo Creek
Strait of Juan De Fuca
Discovery Bay
City Lake
Delanty Lake
Peterson Lake
Tarboo Lake
Jakeway Creek
Donovan Creek
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Leland Creek
Snow Creek
Houck Creek
Ripley Creek
Howe Creek
Little Quilcene River
Spencer Creek
Maple Creek
Jackson Creek
Jefferson County
Clallam County
Dry Creek
Trapper Creek
Chicken Coop Creek
Jimmycomelately Creek
Townsend Creek
Sequim Bay
Dungeness Creek
Johnson Creek
Big Quilcene River
Tunnel Creek
WRIA 17
Exhibit 6
Estimated Recharge In Inches/Year
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend
(inches/year)
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
Scale 1" = 12,750'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\intersect\working.apr layout: Recharge - Runoff Layout


Bywater Bay
Admiralty Inlet
Mats Mats Bay
Port Ludlow
Teal Lake
Squamish Harbor
Shine Creek
Oak Bay
Mats Mats Creek
Ludlow Creek
East Fork Chimacum Creek
Port Townsend
Port Townsend Bay
Thorndyke Bay
Thorndyke Creek
Horseshoe Lake
Sandy Shore Lake
Lake Ludlow
West Fork Chimacum Creek
Silent Lake
Hood Canal
Anderson Lake
Belausite Lake
Gibbs Lake
Tarboo Bay
Dabob Bay
Tarboo Creek
Cove Creek
Jackson Creek
Strait of Juan De Fuca
Discovery Bay
City Lake
Delanty Lake
Peterson Lake
Tarboo Lake
Donovan Creek
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Leland Creek
Spam Creek
Houck Creek
Barnum Creek
Andrews Creek
Ripley Creek
Little Quilcene River
Howe Creek
Penny Creek
Spencer Creek
Maple Creek
Jackson Creek
Coppercopper Creek
Eagle Creek
Jefferson County
Clallam County
Chicken Coop Creek
Dry Creek
Jimmycomelately Creek
Townsend Creek
Sequim Bay
Dean Creek
Johnson Creek
Big Quilcene River
Tunnel Creek
WRIA 17
Exhibit 7
Estimated Rejected Recharge
(Runoff) in Inches/Year
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend
(inches/year)
Not estimated (bedrock)
ZERO
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
Scale 1" = 12,750'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\intersect\working.apr layout: Recharge - Runoff Layout


Bywater Bay
Admiralty Inlet
Mats Mats Bay
Port Ludlow
Teal Lake
Squamish Harbor
Oak Bay
Port Townsend
Port Townsend Bay
Thorndyke Bay
Hood Canal
Horseshoe Lake
Lake Ludlow
Sandy Shore Lake
Silent Lake
Anderson Lake
Beausite Lake
Gibbs Lake
Tarboo Bay
Dabob Bay
Strait of Juan De Fuca
Discovery Bay
City Lake
Delanty Lake
Peterson Lake
Tarboo Lake
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Lords Lake
Jefferson County
Clallam County
Sequim Bay
T 27 W
T 30 W
T 29 W
T 28 W
R 1 W
R 2 W
R 3 W
R 4 W
36
1
WRIA 17
Exhibit 8
Groundwater Rights - Qa in AF/YR, Consumptive Use Only
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend (acre-ft/year)
0 - 20
>20 - 50
>50 - 100
>100 - 250
>250 - 500
502
533
1200
Scale 1" = 12,750'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\wria17_watquantity.apr layout:11x17_groundwater_rights(Qa)

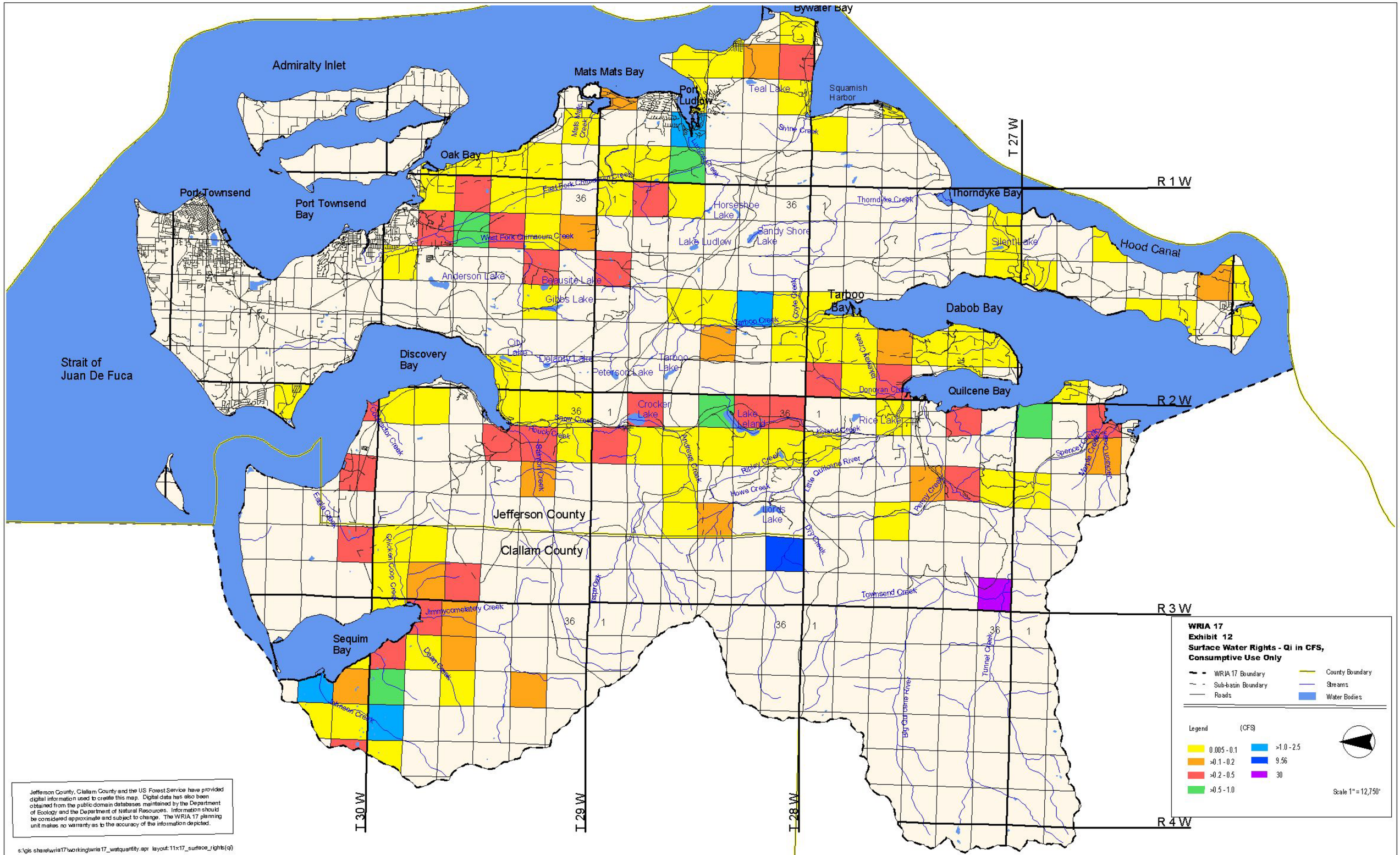

Bywater Bay
Admiralty Inlet
Mats Mats Bay
Port Ludlow
Teal Lake
Squamish Harbor
Shine Creek
Oak Bay
Port Townsend
Port Townsend Bay
East Fork Chimacum Creek
West Fork Chimacum Creek
Horseshoe Lake
Sandy Shore Lake
Lake Ludlow
Thorndyke Bay
Thorndyke Creek
Silent Lake
Hood Canal
Anderson Lake
Beausite Lake
Gibbs Lake
Tarboo Bay
Dabob Bay
Tarboo Creek
Coyle Creek
Strait of Juan De Fuca
Discovery Bay
City Lake
Delanty Lake
Peterson Lake
Tarboo Lake
Jackman Creek
Donovan Creek
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Snow Creek
Houck Creek
Collector Creek
Salmon Creek
Andrews Creek
Leland Creek
Ripley Creek
Howe Creek
Little Quilcene River
Lords Lake
Dry Creek
Penny Creek
Spencer Creek
Marine Creek
Jackson Creek
Jefferson County
Clallam County
Chicken Coop Creek
Jimmycomelately Creek
Sequim Bay
Dean Creek
Johnson Creek
Townsend Creek
Big Quilcene River
Tunnel Creek
T 27 W
R 1 W
R 2 W
R 3 W
R 4 W
T 30 W
T 29 W
T 28 W
36
1
WRIA 17
Exhibit 9
Groundwater Applications - Qi in GPM, Consumptive Use Only
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend
(GPM)
0 - 25
>25 - 50
>50 - 100
>100 - 250
>250 - 500
>500 - 1000
2000
Scale 1" = 12,750'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\wria17_watquantity.apr layout:11x17_groundwater_apps(Qi)

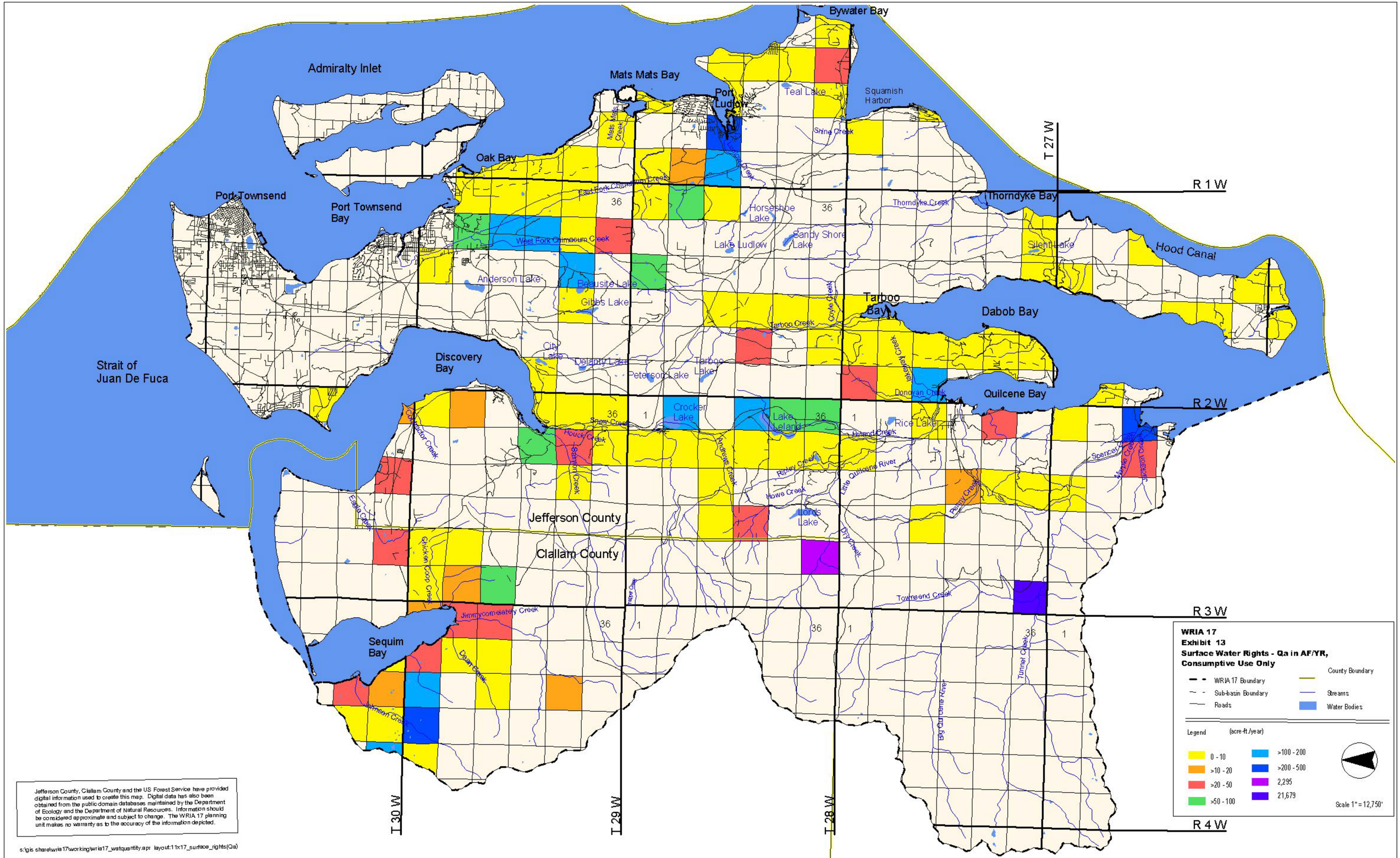

Admiralty Inlet
Mats Mats Bay
Bywater Bay
Port Ludlow
Teal Lake
Squamish Harbor
Oak Bay
Port Townsend
Port Townsend Bay
Thorndyke Bay
Hood Canal
Horseshoe Lake
Lake Ludlow
Sandy Shore Lake
Silent Lake
Anderson Lake
Beausite Lake
Gibbs Lake
Tarboo Bay
Dabob Bay
Strait of Juan De Fuca
Discovery Bay
Delaney Lake
Peterson Lake
Tarboo Lake
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Jefferson County
Clallam County
Lords Lake
Sequim Bay
T 27 W
R 1 W
R 2 W
R 3 W
R 4 W
T 30 W
T 29 W
T 28 W
WRIA 17
Exhibit 10
Count of Groundwater Claims per Section, Consumptive Use Only
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend (No Claims)
0 - 10
>10 - 20
>20 - 30
>30 - 40
>40 - 50
>50 - 75
82
158
720
Scale 1" = 12,750'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\wria17_watquantity.apr layout:11x17_groundwater_claims(Qa)



Note: Values based on an assumed residential use of 250 gallons per day.

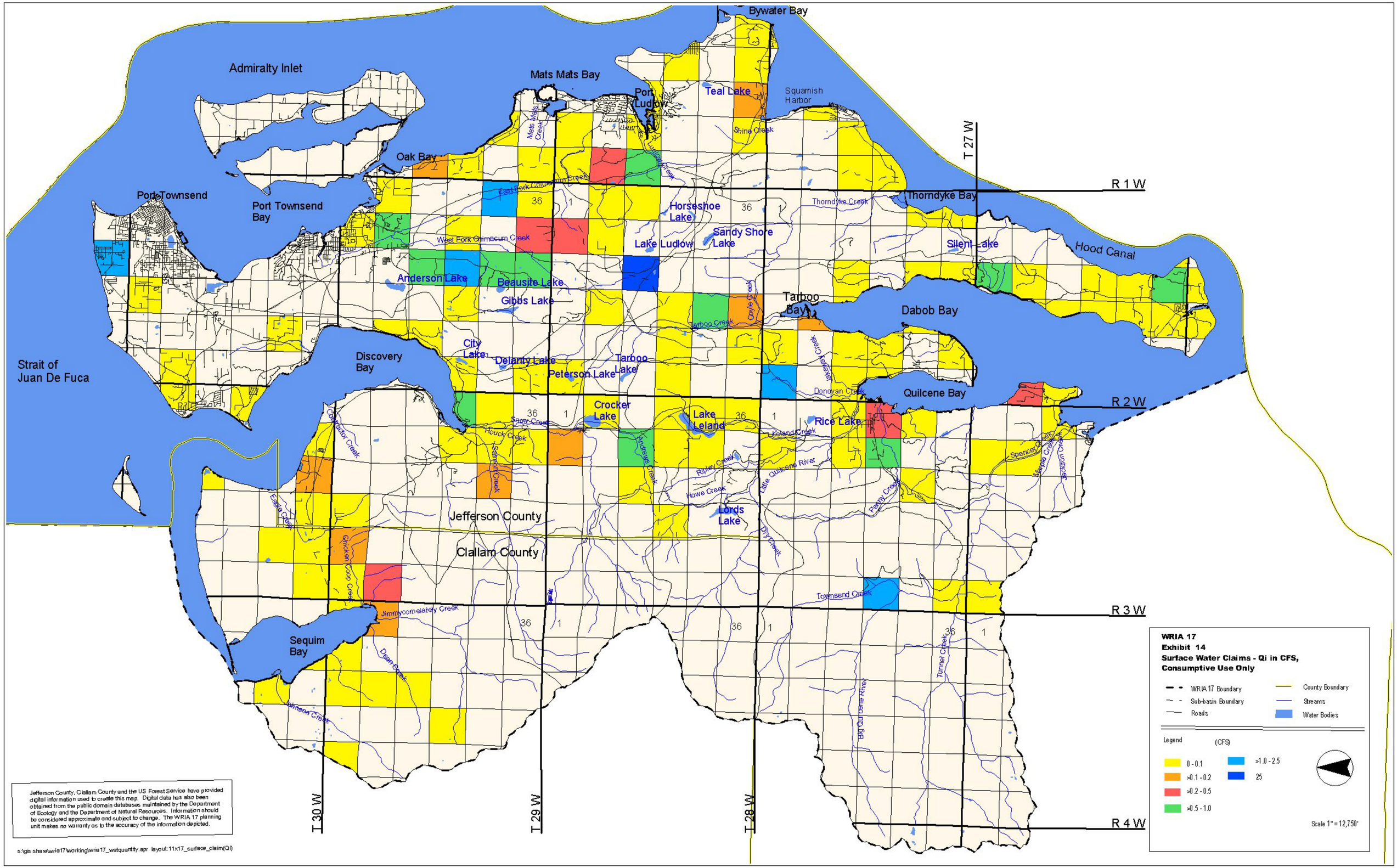
Groundwater use from single family domestic wells based on counts of well logs rather than population estimates (see text).

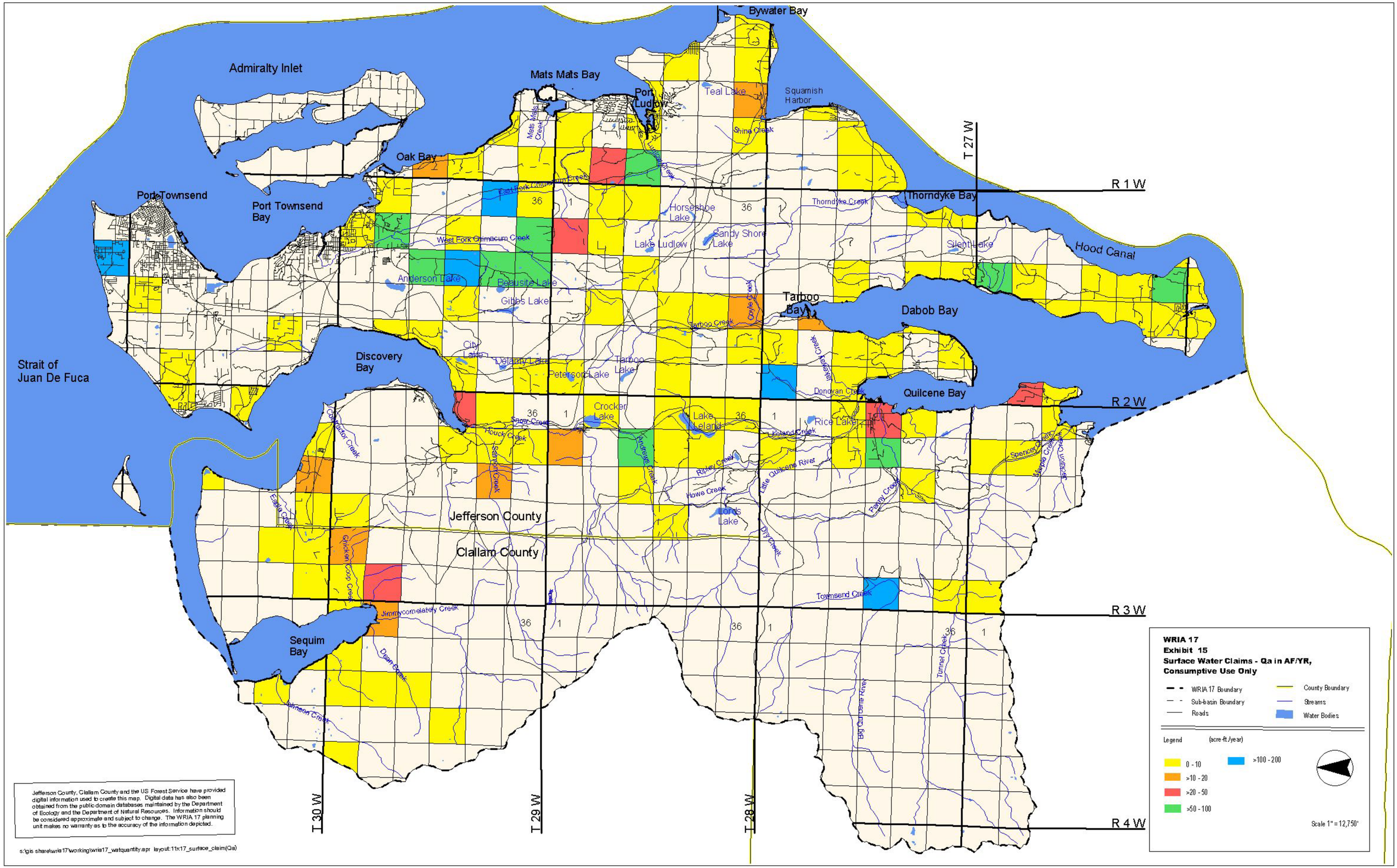

Bywater Bay
Admiralty Inlet
Mats Mats Bay
Port Ludlow
Teal Lake
Squamish Harbor
Oak Bay
Port Townsend
Port Townsend Bay
Thorndyke Bay
Hood Canal
Horseshoe Lake
Sandy Shore Lake
Lake Ludlow
Silent Lake
Anderson Lake
Beausite Lake
Gibbs Lake
Tarboo Bay
Dabob Bay
Strait of Juan De Fuca
Discovery Bay
City Lake
Delanty Lake
Peterson Lake
Tarboo Lake
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Jefferson County
Clallam County
Lords Lake
Sequim Bay
T 27 W
R 1 W
R 2 W
R 3 W
R 4 W
T 30 W
T 29 W
T 28 W
WRIA 17
Exhibit 12
Surface Water Rights - Qi in CFS, Consumptive Use Only
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend (CFS)
0.005 - 0.1
>0.1 - 0.2
>0.2 - 0.5
>0.5 - 1.0
>1.0 - 2.5
9.56
30
Scale 1" = 12,750'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\wria17_watquantity.apr layout:11x17_surface_rights(qi)

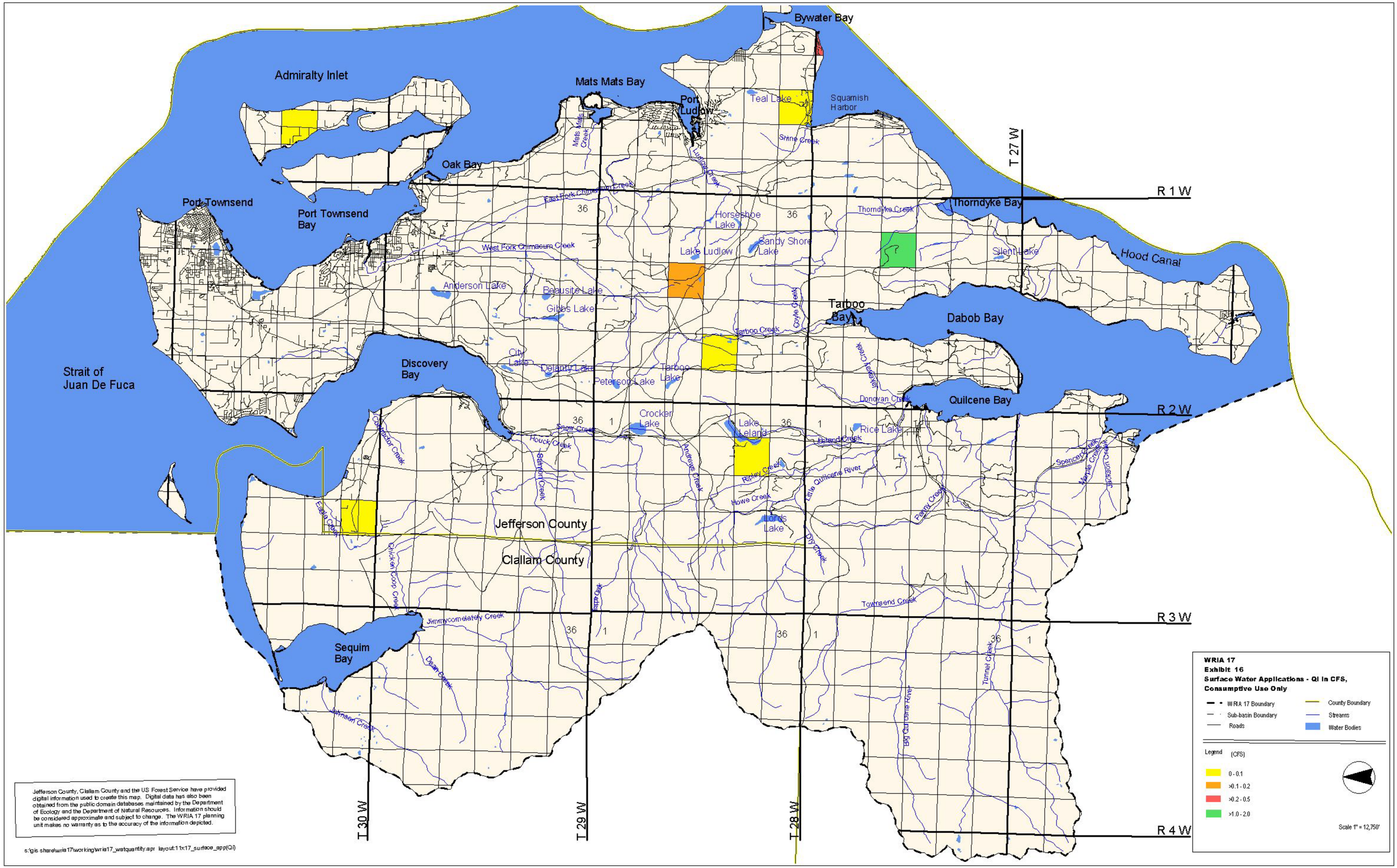


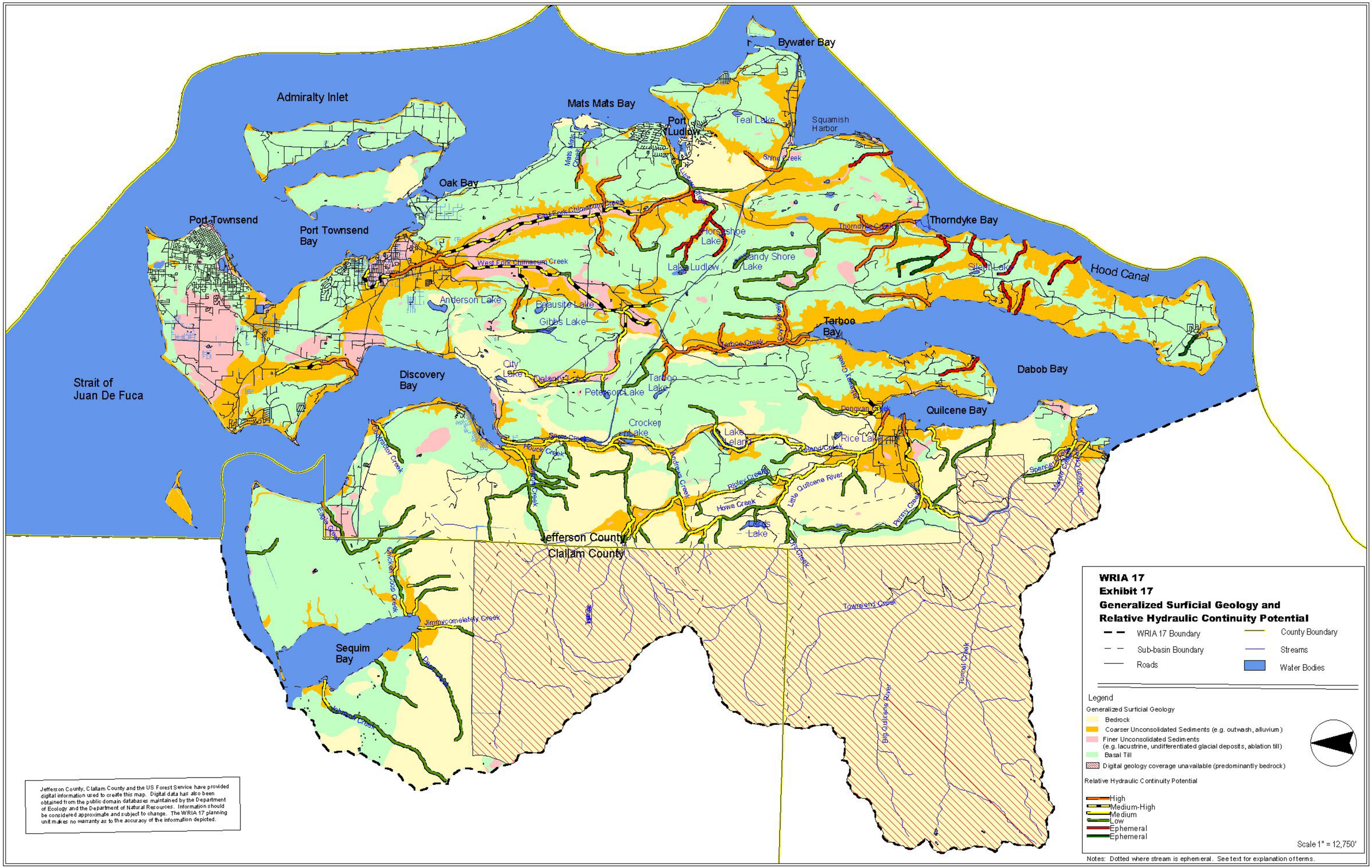
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.

s:\gis share\wria17\working\wria17_watquantity.apr layout:11x17_surface_rights(Qa)

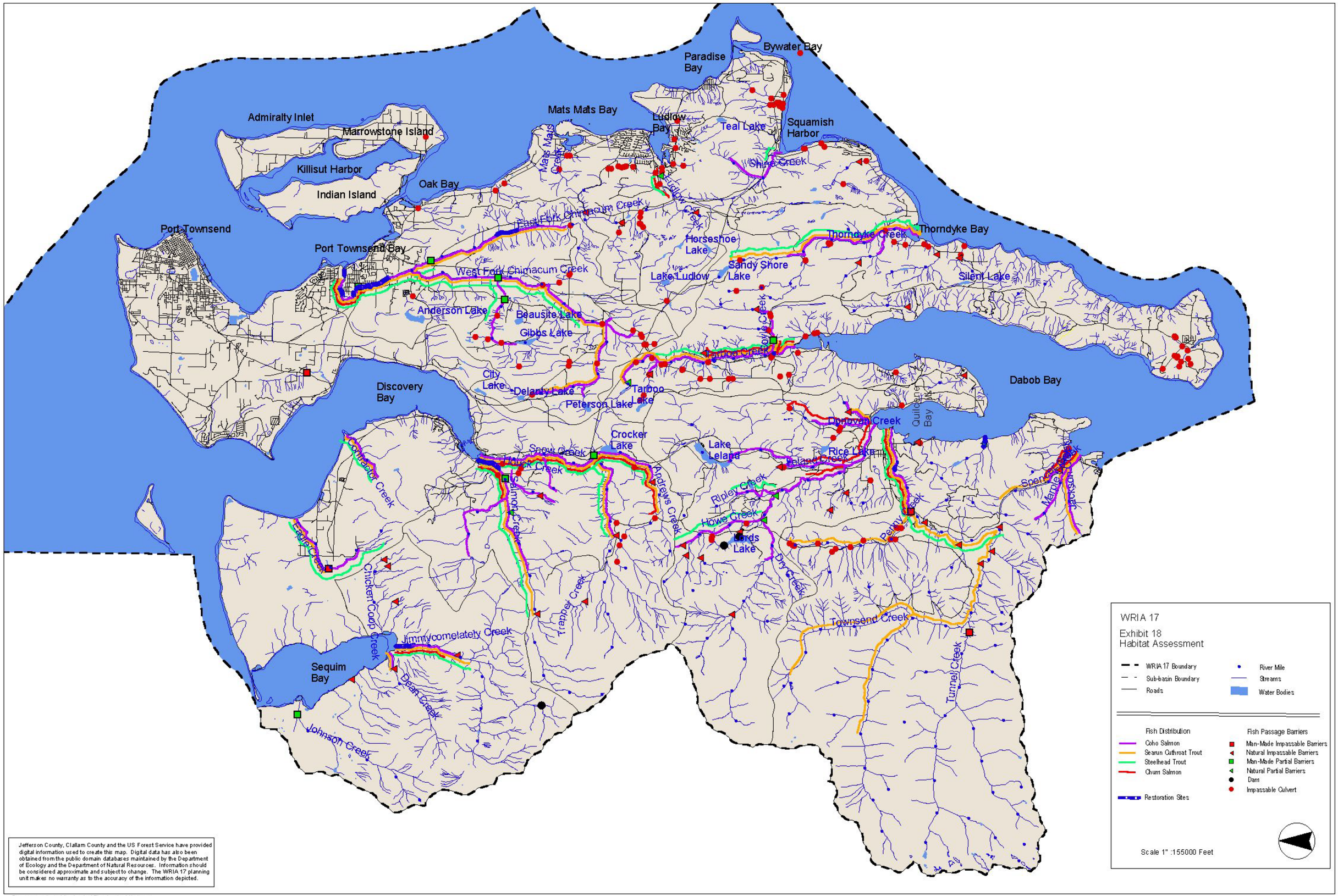

Admiralty Inlet
Bywater Bay
Mats Mats Bay
Port Ludlow
Teal Lake
Squamish Harbor
Oak Bay
Port Townsend
Port Townsend Bay
Thorndyke Bay
Horseshoe Lake
Sandy Shore Lake
Lake Ludlow
Silent Lake
Hood Canal
Anderson Lake
Beausite Lake
Gibbs Lake
Tarboo Bay
Dabob Bay
Strait of Juan De Fuca
Discovery Bay
City Lake
Delanty Lake
Peterson Lake
Tarboo Lake
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Lords Lake
Jefferson County
Clallam County
Sequim Bay
R 1 W
R 2 W
R 3 W
R 4 W
T 27 W
T 30 W
T 29 W
T 28 W
36
1
WRIA 17
Exhibit 14
Surface Water Claims - Qi in CFS,
Consumptive Use Only
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend
(CFS)
0 - 0.1
>0.1 - 0.2
>0.2 - 0.5
>0.5 - 1.0
>1.0 - 2.5
25
Scale 1" = 12,750'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\wria17_watquantity.apr layout:11x17_surface_claim(Qi)


Admiralty Inlet
Bywater Bay
Mats Mats Bay
Port Ludlow
Squamish Harbor
Teal Lake
Oak Bay
Port Townsend
Port Townsend Bay
Thorndyke Bay
Thorndyke Creek
Horseshoe Lake
Sandy Shore Lake
Lake Ludlow
Silent Lake
Hood Canal
Anderson Lake
Beausite Lake
Gibbs Lake
Tarboo Bay
Dabob Bay
Tarboo Creek
Coyle Creek
Strait of Juan De Fuca
Discovery Bay
City Lake
Delaney Lake
Peterson Lake
Tarboo Lake
Jackson Creek
Donovan Creek
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Leland Creek
Snow Creek
Houck Creek
Sampson Creek
Andrews Creek
Ripley Creek
Howe Creek
Little Quilcene River
Lords Lake
Penny Creek
Spencer Creek
Harris Creek
Jackson Creek
Eagle Creek
Jefferson County
Clallam County
Chicken Coop Creek
Dry Creek
Townsend Creek
Jimmycomelately Creek
Sequim Bay
Dean Creek
Johnson Creek
Big Quilcene River
Tunnel Creek
T 27 W
R 1 W
R 2 W
R 3 W
R 4 W
T 30 W
T 29 W
T 28 W
36
1
WRIA 17
Exhibit 15
Surface Water Claims - Qa in AF/YR,
Consumptive Use Only
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend
(acre-ft./year)
0 - 10
>10 - 20
>20 - 50
>50 - 100
>100 - 200
Scale 1" = 12,750'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\wria17_watquantity.apr layout:11x17_surface_claim(Qa)


Admiralty Inlet
Mats Mats Bay
Bywater Bay
Port Ludlow
Teal Lake
Squamish Harbor
Oak Bay
Port Townsend
Port Townsend Bay
Thorndyke Bay
Hood Canal
Horseshoe Lake
Lake Ludlow
Sandy Shore Lake
Silent Lake
Anderson Lake
Beausite Lake
Gibbs Lake
Tarboo Bay
Dabob Bay
Strait of Juan De Fuca
Discovery Bay
City Lake
Delanty Lake
Peterson Lake
Tarboo Lake
Quilcene Bay
Crocker Lake
Lake Leland
Rice Lake
Jefferson County
Clallam County
Lords Lake
Sequim Bay
T 27 W
T 28 W
T 29 W
T 30 W
R 1 W
R 2 W
R 3 W
R 4 W
WRIA 17
Exhibit 16
Surface Water Applications - Qi in CFS, Consumptive Use Only
WRIA 17 Boundary
Sub-basin Boundary
Roads
County Boundary
Streams
Water Bodies
Legend (CFS)
0 - 0.1
>0.1 - 0.2
>0.2 - 0.5
>1.0 - 2.0
Scale 1" = 12,750'
Jefferson County, Clallam County and the US Forest Service have provided digital information used to create this map. Digital data has also been obtained from the public domain databases maintained by the Department of Ecology and the Department of Natural Resources. Information should be considered approximate and subject to change. The WRIA 17 planning unit makes no warranty as to the accuracy of the information depicted.
s:\gis share\wria17\working\wria17_watquantity.apr layout:11x17_surface_app(Qi)



File: GIS Share/WRIA 17/Working/Intersect/Working.apr



Source: c:\working\wria17\wria_habitat.apr