Comments To Deschutes County Planning Commission
Regarding Pot Planning In Deschutes County Oregon
(11/16/15)
Corrected Version

My name is Steve Munson. I was a resident of Deschutes County living in Tumalo area for about 9 years. Most recently I lived about 3 months of the past 18 months at the Tumalo OR ranch where I had previously resided 2008 thru early 2014 and nearby prior to that. I am opposed to pot smoking and to put growing. I do seek to assist some reasonable accords taking place soon between diametrically opposed pot growers and pot opponents. It is my primary intent to protect our ranch open spaces, their values and lifestyles.

This Planning Commission is aware that many opponents of their current direction are very much opposed to the fast track schedule being driven by pot grower advocates on the Deschutes Planning Commission and at least two of the three Deschutes County Commissioners.

One county commissioner spoke at the Friday November 13 meeting in opposition to this accelerated schedule and suggested (in essence) that much more time is required to deal with issues being raised by opponents. I suggested months not weeks are required.

I requested significant time to respond to the newly proposed 50 page set of standards prepared by pot growers.

Instead, after 3 hours of opposition testimony, and after 28 of about 31 comments reported by attendee in the prior meeting who also opposed the earlier shorter version of this pot plan, this Planning Commission allowed a mere two (2) days over the weekend to deal with complex issues.

These issues and phoney pot regulations affect: the value of the primary store of wealth of thousands of Deschutes County residents, which are their homes and farms, over $ 1 billion of value in TID alone, their lifestyle and literally the safety of families and their children.

That is completely wrong. IT MUST BE REVISED IMMEDIATELY. I demand 15 days to fully respond to this obvious “railroad” of new regulation driven by pot growers, many of whom are new to our area.

Many land owners complained they had not been properly notified of this process. Many complained they were not allowed to vote on opting out. My suggestions have been stated by others and/or were supported at the meeting. We estimate about 100 local citizens were at the November 13 meeting and virtually all of them opposed the Planning Commission supported pot growers standards.

These comments to the Deschutes County Planning Commission are meant for inclusion in its near term report to the Deschutes County Commissioners. These comments focus on the following primary issues which require detailed evaluation of the validity and/or the implications of these concerns.

1. Pot Grower Potential Water Use Violations

Water From Federal Land: Discharge Impact Endangered Bull Trout Habitat

Potential Violation Of Ag Water Rights Acreage Limits

Potential Violation Federal Endangered Bull Trout Habitat Protection

2. Oregon Rural Land Use Board (LUBA) Potential Permit Violations

3. Pot Exclusion Zones Inside All County Irrigation District Boundaries

4. Increase Sheriff Nelson's Pot Enforcement Budget $ 2 Million Now

5. Appoint 50 % Pot Opponents To Pot Planning Committee Now

6. Planning Commission Suggest County Commissioners Opt Out Now

7. Form Pot Growers Cooperative And Negotiate County Safe Zones

8. Locate All Growers In County Industrial Zones: Sherriff. OLCC.

9. Three Deschutes County Commissioners Opt Out December 2015

10. Deschutes County Opt Out Vote ASAP 4 Cities and Unincorporated

Continued next page

1. Pot Grower Potential Water Use Violations

Deschutes Water From Federal Lands. The vast majority of all Deschutes County water, stream and groundwater, originates on Federal lands as does the vast majority of all water resource discharge, surface and groundwater.

Endangered Bull Trout Habitat. In addition the natural discharge cold springs into the lower Deschutes River comprise Federal endangered Bull Trout habitat. It is now established fact the Bull Trout critical habitat is adversely affected by water withdrawals upstream in Deschutes County. (See Deschutes Basin Map next page.)

(Also refer to public 2008 Deschutes Basin independent water report for the Thornburg Resort permit process alluded to the letter described below.)

It is highly likely the new Deschutes Basin water resources study and report which the Oregon Department of Fish and Wildlife demanded to the **Deschutes County Planning Commission** by letter **November 6, 2015** will further curtail planning regarding water use approvals and mitigation programs allowable, if any, by the Deschutes Planning Commission. The water use letter which is attached deals with the Thornburgh Resort. It also will require evaluation of other large potential new withdrawals, like pot.

(Sett 11/1/15 letter to Deschutes County Planning Commission attached.)

It is incumbent on the Deschutes Planning Commission and the Deschutes County Commissioners not to rush forward with any pot grower plans or approvals until their impacts upon Deschutes Basin water supplies and on the Federal endangered Bull Trout habitat are evaluated and reported on.

Potential Violation Of Ag Water Rights Acreage Limits. Deschutes County ag water permits are stated in terms of feet of water per year per acre. From current water use statements of pot growers their water use vastly exceeds allowable water per acre standard. Likely by ratio of over 10 to 1.

Potential Violation Federal Endangered Bull Trout Habitat Protection
This concern is covered by the first comment above on the Oregon Dept of Fish and Game letter of 11/6/15 to the Deschutes County Planning Commission.

It is our opinion this water issue alone is sufficient cause for the Deschutes Planning Commission to advise County Commissioners to opt out now. At a minimum it obviously requires substantial time to evaluate, report and make allowances in planning decisions regarding commercial pot grower impacts.

2. Oregon Rural Land Use Board (LUBA) Potential Permit Violations

The county has not yet made available the video and/or tape of the meeting last Friday evening. Hence we do not yet have names of numerous local citizens who spoke in opposition to the proposed new pot grower standards.

One opponent spoke eloquently and appeared well informed on the Oregon Land Use Board permit process. He cited a list of 5 major reports which are required under Oregon law to construct and operate pot operations. He stated many operations are now in violation and many more are in process which together represent an enormous and illegal "gutting" or Oregon land use law.

It is our opinion this land permit issue alone is sufficient cause for the Deschutes Planning Commission to advise County Commissioners to opt out now. At a minimum it obviously requires substantial time to evaluate, report and make allowances in planning decisions regarding commercial pot grower impacts.

3. Set Pot Exclusion Zones Inside County Irrigation District Boundaries

Over 100 Deschutes County residents have spoken out in the past two weeks in opposition to the pot grower deplorable adverse effects on their lifestyles, their property values, their view, the horrid disgusting stench of pot and the coming dangers to themselves and children from adjacent stoned pot workers and/or buyers. They objected to night lights in violation of code and law. They objected to what appear to be illegal grow operations now.

One Planning Commissioner, recently arrived from Humbolt County, bragged about his affiliations there, his knowledge of pot growing, as though we are stupid ranchers who just fell off the turnip truck. We are not. The ranks of opponents are filled with former well educated senior executives, the former colonel of the Air Force Top Gun Fighter School, major highly successful cutting and reining horse ranch owners.

All of us have invested large sums, for retirement, enjoyment and business in our properties. Wee don't want them destroyed by pot, by growers, by workers, by stomach churning stench, by gangs fighting over the product. There are now about 1500 property addresses in TID boundaries. That is very roughly 3000 to 5000 resident citizens. The irrigated lands in Deschutes County likely contain 15,000 to 20,000 people, most here to enjoy this wonderful place. The pot growers likely comprise 5 to 15 biggies and a bunch of medicinal growers who want to expand if this abomination of planning proceeds.

Many of us say NO to their plans. We are in many ways the backbone of this county and have been since its inception over 100 years ago. Nothing against the city folks here. We have lots of friends in towns of course. In fact many of them love and use our outdoors as well. But lets not ruin what we have.

For these reasons I suggested at the meeting and I suggest again hereby that we NOW put a boundary, by and through the Deschutes County Planning Commission to be advised to County Commissioners, which excludes pot growing inside of each and every irrigation district in Deschutes County.

Then we can vote later on opting out or not. See # 10 below.

4. Increase Sheriff Nelson's Pot Enforcement Budget $ 2 Million Now

Pot opponents living on rural lands met with County Commissioner Alan Unger and with County Sheriff Nelson. The Sherriff has spoken eloquently about the need for large funds to safeguard citizens and, yes, growers too. Opponents asked Commissioner Unger if it was true, as pot growers stated, that the county did not have money it could provide to rural law enforcement. He reportedly stated, its not right. We have plenty of money.

Accordingly I suggest and demand County Commissioners immediately provide Sherriff Nelson the sum of $ 2 million of county funds to hire, train, and enforce pot laws NOW and into the future. The funds may be enough to hire and train 25 or more deputies and staff, cars, pot scent dogs, test lab and ongoing expenses. If and when the pot business is moved to secure county zoned land with fencing, the county should pay for Sheriff offices there too.

If these Commissioners want to support pot, then they need to act like adults and fund this now like they give a damn about citizens who suffer impacts.

5. Appoint 50 % Pot Opponents To Pot Planning Committee Now

Opponents have tried without success to join the pot planning committees in this area. They have been blocked by pot growers and their allies on the Planning Commission and/or County Commissions.

This is actually bad for both pot growers and others. It puts the growers in isolation and is going to predictably result in vast litigation and delays for years by pot opponents who are only now learning of the impacts and are only now beginning to voice their outrage.

I suggest that pot planning committee members NOW be splt evenly between growers-supporters and opponents. Then work can start on fixing the mess created by self-serving largely outside interests at our expense.

6. Planning Commission Suggest County Commissioners Opt Out Now

Many opponents have demanded the two members opt out NOW, of the County Commission, Unger and DeBone, who "took the bit in their teeth" and the "law into their own hands" when the two of them refused to opt out

I agree as did many who spoke up and who met after the Friday meeting. I request the Deschutes County Plannning Commission advise the Deschutes County Commissioners OPT OUT NOW, in December 2015.

I suggest they do so in a way that puts us all in Deschutes County on course to a county-wide vote within about 6 months when all issues are settled by necessary reports, evaluation and informed planning.

As stated above, with even division on pot planning committee, the growers and would be growers can negotiate settlement with opponents as well. It is suggested a "Pot Settlement" include the following major provisions.

7. Form Pot Growers Cooperative And Negotiate County Safe Zones

Both myself, not in favor of either pot smoking or growing, and the other signatory to this Comment Letter, Lou Gillette who is a legal medicinal pot grower suggest the Deschutes County Pot Growers from a cooperative.

We further suggest they find agreement with county and city and economic development agencies to locate all pot growing inside county designated save zones, outside the irrigation district areas, but served by water and electric utilities. It is our understanding that some La Pine area growers have suggested creating such a zone in the county-owned industrial park land which exceeds needed acreage.

We both concur with that idea. We suggest Bend and Redmond industrial areas also be considered as well.

8. Locate All Growers In County Industrial Zones: Sherriff. OLCC.

It is our second-hand understanding from opponents we have both met with that Sherriff Nelson also supports a concept like this. It is our second-had understanding our county Sherriff has stated his department cannot do its job of providing citizen safety with its current budget and likely not unless pot growers are centralized for regulation and safety purposes.

We concur with the idea that both a county sheriffs office and OLCC lab be co-sited with pot growers for both safety and efficient operations reasons. In a cooperative arrangement both small and large growers can succeed.

9. Three Deschutes County Commissioners Opt Out December 2015

As stated above, we proposed the County Commissioners opt out for this county in December 2015 after getting the above stated ROT REFORMS fully underway. Then they will have done their job under admittedly tough conditions. We can only note, the time jam was created by intent. It need not have been handled in this way, but these suggestions can allow settlements.

10. Deschutes County Opt Out Vote ASAP 4 Cities and Unincorporated

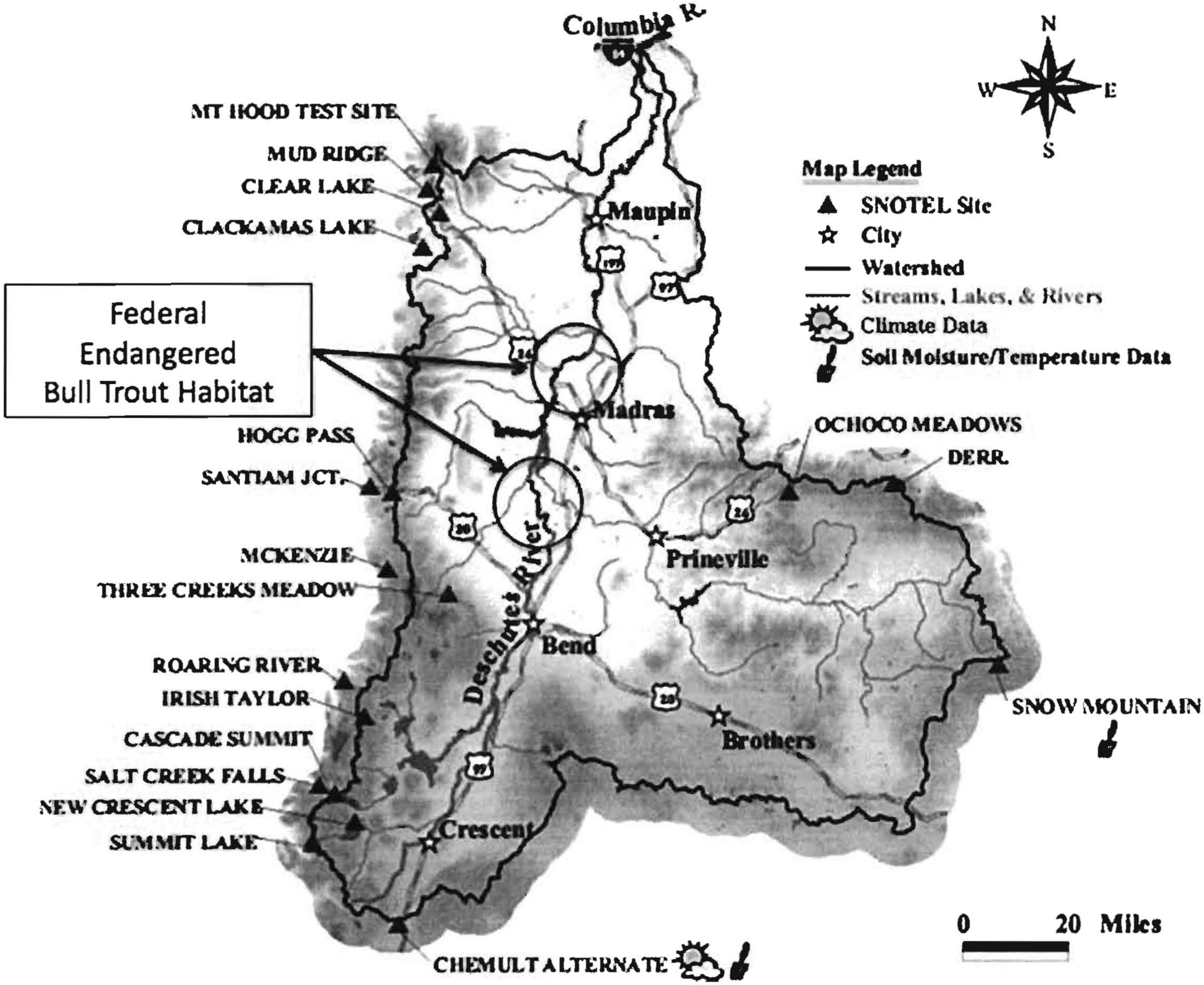
We suggest a county-wide vote on opting out or not opting out to be held not later than June 30 2016.

We suggest voting be tabulated and areas be designated by the following five (5) voting majorities within the following boundaries:

Bend, Redmond, Sisters, La Pine and also by the Unincorporated County.

More I saith not.
Date: 11/16/15

Steve Munson


Columbia R.
MT HOOD TEST SITE
MUD RIDGE
CLEAR LAKE
CLACKAMAS LAKE
Maupin
Map Legend
SNOTEL Site
City
Watershed
Streams, Lakes, & Rivers
Climate Data
Soil Moisture/Temperature Data
N
W
E
S
Federal Endangered Bull Trout Habitat
Madras
HOGG PASS
SANTIAM JCT.
OCHOCO MEADOWS
DERR.
Prineville
MCKENZIE
THREE CREEKS MEADOW
Deschutes River
Bend
ROARING RIVER
IRISH TAYLOR
CASCADE SUMMIT
SALT CREEK FALLS
NEW CRESCENT LAKE
SUMMIT LAKE
Crescent
Brothers
SNOW MOUNTAIN
0 20 Miles
CHEMULT ALTERNATE

Oregon
Kate Brown, Governor

Department of Fish and Wildlife
Deschutes Watershed District
East Region
61374 Parrell Road
Bend, Oregon 97702
(541) 388-6363
FAX (541) 388-6281

OREGON Fish & Wildlife

November 6, 2015

Deschutes County
Community Development Department
Planning Division
117 NW Lafayette Ave
Bend, OR 97701
ATTN: Peter Gutowsky

RE: Thornburgh Resort Company-Final Master Plan Remand

The purpose of this letter is to clarify Oregon Department of Fish and Wildlife's (Department) recommendation whether fish and wildlife mitigation proposed in the Thornburg Resort Company Final Master Plan meets a No Net Loss standard.

Based on new information and changes since 2008 the Department believes there is significant uncertainties as to whether a No Net Loss standard is being met by the proposed mitigation. Thus, we recommend a reassessment needs to be conducted.

On Friday October 31, 2015 I sent an email to Kameron DeLashmutt which I understand was forwarded to you by him. Based on information I was not aware of at the time of sending that email and on further review, the Department is retracting that email and statements in it.

In addition, the Department is retracting all statements made in our June 13, 2008 letter to the County regarding adequacy of proposed mitigation to address fish and wildlife impacts from resort development. Specifically, the Department is retracting the statement:

"*ODFW has determined that providing the proposed mitigation outlined above should mitigate for potential impacts on springs and seeps and provide a net benefit to the resource.*"

At this time the Department does not believe that the proposed mitigation has been shown to be adequate to meet a No Net Loss standard and to do so there needs to be a reassessment.

The Department requests that the record in this matter on fish and wildlife issues be reopened for a new assessment, given new information and other changes since June of 2008.

On the Deschutes River, a re-analysis is needed of whether the Deep Canyon Creek springs proposed for mitigation will provide long-term cold water mitigation giving the declining water table identified in the 2013 USGS Scientific Investigations Report 2013-5092 titled "*Analysis of 1997-2008 Groundwater Level Changes in the Upper Deschutes Basin, Central Oregon.*" The report indicates that groundwater appears to be declining in the Central Deschutes Area about 1 foot per year. Given this new information, we are not sure the Deep Canyon Creek springs will persist and actually provide the proposed mitigation.

As for mitigation in Whychus Creek subsequently proposed by the Resort, the Department was unaware of such a proposal at the time of our June 13, 2008 letter and thus did not comment on the proposal's adequacy.

It is our position however, that warmer instream water as proposed would not mitigate to No Net Loss for lost cold spring water. Flow changes in Whychus Creek over the past seven years, including this year's drought, need to be assessed, as well as any new information on the springs in the lower Creek.

We also believe a reassessment is needed of the proposed wildlife mitigation to assess changes on the land in the Cline Buttes area and management of it over the past seven years.

Thank you for the opportunity to comment.

Sincerely,

Robert M. Hooton

Robert M. Hooton
Deschutes Watershed District Manager

DESCHUTES COUNTY COMMISSIONERS
PUBLIC HEARING TESTIMONY

Meeting: December 2 2015

"LAND USE REGULATIONS"
IN
UNICORPORATED DESCHUTES COUNTY

For This Public Record
Previously Submitted In Other Water Evaluation Processes
Independent Reports Commissioned For Various Evaluation Uses

Independent Deschutes Basin Water Resources Reports
Reports Cover: Proposed Thornburg Resort Water Issues
Deschutes Basin Water Resources: Including Drawdowns Prior 10 Years

By Mark Yinger Associates
(Sisters Oregon)

DESHUTES COUNTY COMMISSIONERS
PUBLIC HEARING TESTIMONY
Meeting: December 2 2015

"LAND USE REGULATIONS"
IN
UNICORPORATED DESCHUTES COUNTY

Steve Munson Tumalo Ranch LLC
Expert Witness On
High Desert Horse Ranch Operations
Cofounder With Sandy Lonsdale. Far West "Born of Fire Consortium"
Tumalo Native Bunchgrass and Forest Restoration and Water Effects

Sisters Wilderness Bill Proponent Including US Congress Film
Planting Willows In Klamath Marsh: Wendell Wood, Others.
Executive Producer: 2011 Emmy-Energy Nominated Documentary Film
"**Houston We Have A Problem**"

Deschutes Basin Water Resource Drawdown Independent Reports
Sponsor Of Independent Yinger Reports On Basin and Thornburgh Resort
Federal Endangered Bull Trout Critical Habitat Protections

Primary Leadership Of Following Oregon Landmark Legislation:
Gov Tom McCall. Sen George Wingard. Speaker Of House Bob Smith.
Executive Director: Steve Munson
Oregon House Task Force On Pollution
Oregon Air and Water Pollution Protections
Oregon Land Use Process Protections
Nuclear Plant Siting

Green Power Laws History Of Steve Munson
A Leader In 5 States: NV CA NM TX OR
Oregon Renewable Portfolio Standard (RPS)
US Senator # 1: "An American Hero' US Senator # 2 "Mr RPS"

Education: Redmond Union High School 1961
UofO BS. Stanford B School: MBA Finance. Stanford: MA Pol Scienc

Projected Financial Losses Of Deschutes County "Going To Pot"
Property Owners Value Losses. County Tax Revenue Losses.
(Dollars In Millions)

Chart 1 2014 Property Assessed Valuations (1)		
County Areas	**Valuations**	**Tax Due Assessed**
Exclusive Farm Use:		
Unincorporated Area:		
Bend:		
Redmond:		
Sisters:		
La Pine:		
Subtotal Cities		
TOTAL County	**$ 20.9 Billion**	**$ 298 Million**
Note: (1) Due to payment timing difference, penalty, other: actual July 2104 to June 2015 total property tax payments to county was $ 318 million. Only data easily available for this report are total county numbers above.		

The balance of missing data makes the case that county commissioners **MUST OPT OUT.** Then gather and report the: **Property Valuations** and **Tax Revenues** and **Cost Benefits Analysis** data to public. Deschutes County citizens vote in election after mid 2016, if public gets data with 3 months to fact check and to evaluate. **Then hold fully informed election.** Data and report must be impartially sourced. Not another pot committee.

CHART 2

Estimated Maximum Property Owners and County Losses Property Owners Value Losses. County Tax Revenue Losses					
Years	2016	2017	2018	2019	2020
Owners Loss (%)	10%	20%	30%	40%	50%
County Tax Loss (%)	10%	20%	30%	40%	50%

Maximum Property Owners Losses By Area (Dollars In Billions)					
Years	2016	2017	2018	2019	2020
Exclusive Farm Use					
Unincorporated Area					
Bend:					
Redmond:					
Sisters:					
La Pine:					
Subtotal Cities					
TOTAL County **($20.9 Billion)**	**$2.1 B**	**$4.2 B**	**$6.3 B**	**$8.4 B**	**$10.5 B**

Estimated Minimum Property Owners and County Losses Property Owners Value Losses. County Tax Revenue Losses					
Years	2016	2017	2018	2019	2020
Owners Losses (%)	5%	10%	15%	20%	25%
County Tax Loss (%)	5%	10%	15%	20%	25%

Minimum Property Owners Losses By Area (Dollars In Billions)					
Years	2016	2017	2018	2019	2020
Exclusive Farm Use					
Unincorporated Area					
Bend:					
Redmond:					
Sisters:					
La Pine:					
Subtotal Cities					
TOTAL County **($20.9 Billion)**	**$1.1 B**	**$2.1 B**	**$3.1 B**	**$4.2 B**	**$5.2 B**

CHART 3

Estimated Maximum Property Owners and County Losses Property Owners Value Losses. County Tax Revenue Losses (2)					
Years	2016	2017	2018	2019	2020
Owners Loss (%)	10%	20%	30%	40%	50%
County Tax Loss (%)	10%	20%	30%	40%	50%

Maximum County Tax Revenue Losses By Area (2) (Dollars In Millions)					
Years	2016	2017	2018	2019	2020
Exclusive Farm Use					
Unincorporated Area					
Bend:					
Redmond:					
Sisters:					
La Pine:					
Subtotal Cities					
TOTAL County					

Estimated Minimum County Tax Revenue Losses By Area Property Owners Value Losses. County Tax Revenue Losses (2)					
Years	2016	2017	2018	2019	2020
Owners Losses (%)	5%	10%	15%	20%	25%
County Tax Loss (%)	5%	10%	15%	20%	25%

Minimum County Tax Revenue Losses By Area (2) (Dollars In Millions)					
Years	2016	2017	2018	2019	2020
Exclusive Farm Use					
Unincorporated Area					
Bend:					
Redmond:					
Sisters:					
La Pine:					
Subtotal Cities					
TOTAL County					

Deschutes County Property Valuation Tax Effects With No Opt Out And No Cost Benefits Study Planning Documents

Deschutes County Treasurer was asked today if there is a cost benefits financial study he is aware of on potential effects of pot growing on rural lands in county. He is a highly trained public servant who was conversant on every major aspect of county financial operations he was asked about. He reports to the three Deschutes County Commissioners I believe.

He said there is no such study. He was not pressed on the point **Why Not?**

The county collects all property taxes and distributes them to cities and other entities like county law enforcement. County keeps about 12 % of property taxes collected to meet some of its budget: .

Nearly 90 % of county Sherrifs budget comes from property taxes, about $30 million last tax year for two special use law enforcement entities: (1) all county services like jails; and (2) rural resident services.

BIG POTENTIAL PROBLEM....If pot drops county property values enough to also drop property tax revenues as it seems likely to do, then the law enforcement budget will drop: **EXACTLY when we will actually need big Sherriff budget increase to keep our families, houses, properties, animals and children safe from pot-related crime wave across county.**

County Commissioner Unger reportedly stated to Opt Out Proponents that county has plenty of money to much increase Sherriff budget for pot NOW. I proposed immediate county payment increase of $ 2 M to Sherriff for pot related law enforcement. I now think its low. Much more soon, as needed.

Note (2): County Tax Operations Are Complex. A diagram will be submitted later summaring how the county property tax rate and collections are designed and work. By example a few years ago Redmond property tax payment receipts dropped from 87 % of taxpayers, if I correctly understood the brief discussions with knowledgeable county tax officials.

Chart 4 (2)
Deschutes County "Going To Pot" Now Costs and Benefits Analysis
Requires Independent Public Report and 3 Months Review Prior Voting
Not Including Owners and Tax Revenue Losses On Previous Charts Above
(Dollars In Millions)

Annual Pot New Costs and Benefits Analysis: 2016 thru 2020						
	County	Bend	Redmond	Sisters	La Pine	TOTAL
Pot Tax Revenues						
As Per Cent (Proposed)						
Tax County Gov't Revenues						
Plus: Pot Strtucture Tax						
TOTAL Pot Revenues						
Less Go To Pot Costs:						
Law Enforcement (24 hrs)						
Add: 12-15 Pot Staff						
Patrol Cars. Equipment						
Operations Overhead						
Drones-staff: Sniff-Lights						
(cost savings ?)						
School Outreach						
Net New Incarceration (3)						
Inmate Days						
Cost Per Day						
Inmate Costs						
DA/Court Costs (3)						
New Jail (s)?						
Subtotal Law Costs						
Planning Departments.						
Add: Pot bldg permit staff						
Special water use staff						
Pot water meters. Gals/mo.						
Permit Enforcement staff						
Vehicles Overhead						
Other costs						
Subtotal Plan Costs						

CHART 5 Continued: Pot New Costs and Benefits Analysis: 2016 thru 2020						
	County	Bend	Redmond	Sisters	La Pine	TOTAL
Social Services Costs:						
Indigent Family Support						
Medical Services						
Food Payments						
Mental Health						
Other Social Costs:						
1						
2						
3						
4						
5						
Subtotal Social Costs						
Other Costs:						
1 Reduced debt credit ratings?						
2 Violate debt covenants?						
3 Loss new jobs bad image?						
4 Tourism Loss bad image?						
5 Pot use housing loss?						
6						
7						
Subtotal Other Costs						
TOTAL Costs						
TOTAL (Net Costs /Benefits)						

Note: (3) Calculation is net new inmates by combining new pot related crimes inmates (harrasment, driving stoned, violence, pot-money thefts, neighbors goods theft, explosion deaths) and inmate descriminalize reduction.

Chart 6.
Costs and Benefits Comparisons

"Going To Pot" With No Opt Out Policy
Compared To
Three (3) Deschutes County Pot Grow Zones

Opt out. Research. Independent Cost Benefits Reports.
50/50 Committee Negotiate New Plan In First Half Of 2106

It is **highly likely that Cost Benefits Analysis** of a proposed centralized three (3). Pot Growout Zones Plan for Deschutes County will be much more beneficial to our citizens, county and environment **than the contentions course we are on here <u>IF county commissioners do not Opt Out.</u>**

Property owners values are much less likely drop precipitously.

Maintain property tax revenues at the same or higher levels.

Keep life styles, outdoor values, area beauty which attract tourists and jobs.

Our county, our rural areas, our children are likely to be much safer.

Law enforcement, planning department, social service costs much lower.

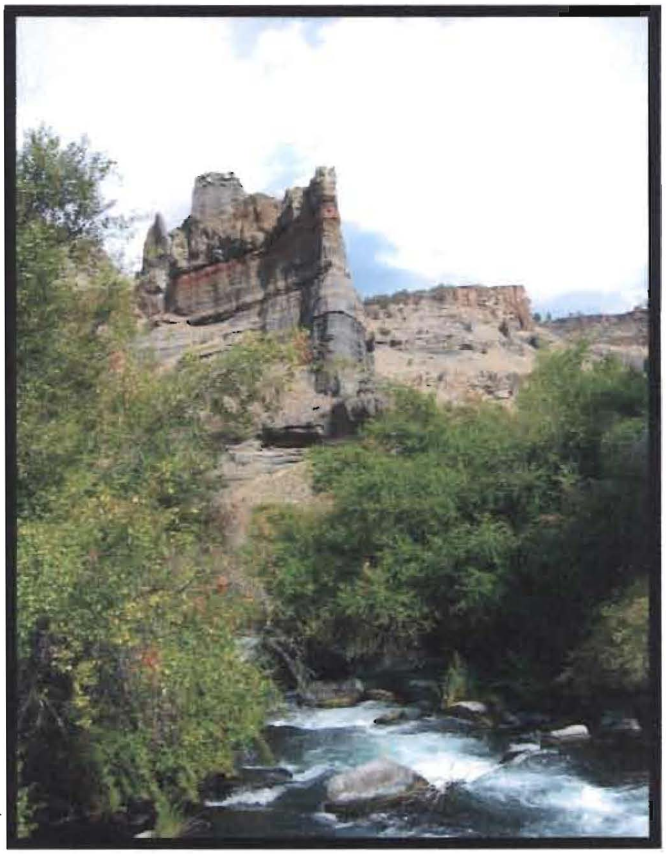
Plan for budges increases of above costs and fund them prior to needs.

Possibly even realize net benefits from pot under 3 Pot Grow Zones Plan.
Pot utility needs include water, heat and power.

We can provide and/or mitigate uses at centralized sites.

A Case Study: Thornburgh Resort Water Resources Impact Evaluation

Upper Deschutes Basin, Oregon



Whychus Creek at the confluence with the Deschutes River.

Mark Yinger Associates

and

Northwest Land & Water, Inc.

February 2008

NORTHWEST Land & Water, INC.

Mark Yinger ASSOCIATES

Case Study:
Thornburgh Resort Water Resources Impact Evaluation
Upper Deschutes Basin, Oregon

Prepared for:
Steve Munson, President
Sandy Lonsdale, Director
Native Restoration Fund
Vulcan Power Company
Bend, OR

Prepared by:
Mark Yinger, R.G.
Mark Yinger Associates
69860 Camp Polk Rd.
Sisters, OR 97759
541-549-3030

and

Laura Strauss, Principal Hydrogeologist, LG, LHg
Northwest Land & Water, Inc.
6556 37th Ave NE
Seattle, WA 98115
www.nlwinc.com
206-525-0049

February 2008

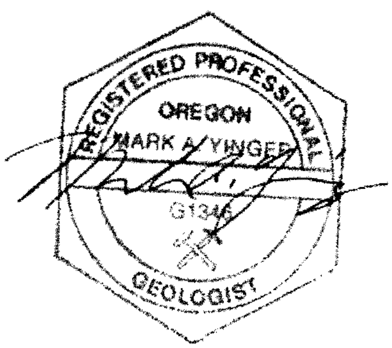


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Table 6-3 Summary of Monthly and Annual Water Use, in Million Gallons, for Selected Private Supply Wells 1997–2006, Upper Deschutes Basin, Oregon

Table 6-4 Total Annual Water Use, in Million Gallons, for Selected Public Supply Wells 1997–2006, Upper Deschutes Basin, Oregon

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1.0 Executive Summary

This report details the results of an investigation conducted to assess the potential impacts of pumping 3.25 cubic feet per second (cfs) of water from six new wells in the Upper Deschutes Basin (UDB). These wells are part of the proposed Thornburgh destination resort, which is located near important ecological resources. The proposed Thornburgh development will exacerbate rising trends in water use, which has increased consistently since 1998. Likewise, water right permits and applications have also increased significantly since 1998. They reflect the history of water rights policy in the UDB.

To assess the potential impacts to ecological resources, we analyzed geologic, water level, climate, streamflow, water use, water quality, temperature, seepage, and habitat data. We also ran a model developed by the U.S. Geological Survey (USGS). Our modeling and hydraulic analyses identified reaches of the middle Deschutes River and lower Whychus Creek that will be impacted by pumping from the proposed Thornburgh wells. Listed critical bull trout, core populations of redband trout, and unique plant communities live within these reaches.

- **Groundwater level impacts**. Declines in groundwater levels are important because they impact not only other water users but also streamflows. Hydraulic and well deepening data indicate that groundwater levels are already declining in parts of the UDB. A concentration of wells has been deepened near the Eagle Crest Resort, which is located a short distance east of Thornburgh, indicating declines. Recent hydrogeologic information for the Cline Buttes area also indicates that impacts to groundwater levels in the Thornburg area will exceed the predictions of the USGS model. The Thornburgh wells will accelerate water level declines, impact existing water wells and reduce streamflows.
- **Water quality impacts**. The temperature in UDB streams currently exceeds the recommended quality for bull trout and general stream health. Cold groundwater discharges are essential to reducing stream temperatures. Pumping from the Thornburgh and other future wells will cumulatively reduce these groundwater discharges if not properly mitigated. More specifically, modeling indicates that pumping from proposed Thornburgh wells would reduce cold spring discharges to the middle Deschutes River and Whychus Creek reaches that have federally listed critical bull trout habitat, core populations of redband trout, and important ecological resources for reintroducing Chinook salmon and summer steelhead. As cold groundwater discharges decline in response to new pumping, warm water will migrate downstream, negatively impacting these resources.

- **Streamflow impacts**. Our analysis indicates that impacts will occur to the middle Deschutes River above RM 125, lower Whychus Creek, and Tumalo Creek. Seepage does not occur consistently along the Deschutes River; rather, it is strong in some places and weak in others, indicating significant preferred groundwater flow paths. River sections with small gains are most vulnerable to small changes in groundwater level. Water temperature in these sections is at great risk of increasing as cool groundwater inflow declines.

Mitigation must be within this zone of impact. The water permit for Thornburgh allows mitigation in the general zone, anywhere in the basin above the Madras gauge. This will result in an unmitigated new groundwater permit. In addition, current mitigation strategies rely on current streamflow measurements to evaluate the effectiveness of the water rights banking system. Streamflows will undoubtedly change in response to declines in precipitation and increased pumping.

Success of the mitigation program must be measured against the goal of moving toward a more natural hydrograph, not by comparing streamflow to the historically lowest streamflow, when diversions were at their maximum.

2.0 Introduction

Development in the Upper Deschutes Basin (UDB) has increased dramatically over the past 20 years. However, land use authorities and regulatory agencies have not required developers to comprehensively evaluate impacts to hydrological (streamflows, aquifer levels) and ecological resources due to new groundwater development. Although the USGS has characterized the hydrogeology of the UDB, the potential impacts to hydrological and ecological resources have not been adequately evaluated. Furthermore, recent data suggests declining trends in both precipitation and groundwater levels. These trends would not only impact streamflows, groundwater levels, and ecological resources of the upper and middle Deschutes River, but they would also be aggravated by future groundwater pumpage if not correctly mitigated.

Key ecological resources along the upper and middle Deschutes River include habitat for native bull and Redband trout; in addition, some reaches contain critical spawning and rearing habitat. Reduced streamflow and discharges from cold springs would impact fisheries. The middle Deschutes canyon is also home to unique riparian habitat.

This study focuses on impacts that a 1,970 acre destination resort planned in Deschutes County will have on water resources and water dependant ecology. In addition to this resort there are fourteen other destination resorts that are either under construction or in some stage of planning in Deschutes, Jefferson and Crook Counties. The total acreage of these resorts may range from 20,000 to 25,000. These destination resorts will rely almost entirely on groundwater. Their impact on water resources will be significant. The impact of each resort and the cumulative impact of all the resorts should be evaluated.

2.1 Proposed Development

Legislation passed in 2005 authorized the allocation of water from the Deschutes River and from the aquifers that feed it during seasons when instream flows are unmet. The legislation allows further groundwater development, which may diminish both quantity and quality of water in the Deschutes River and its tributaries.

A recent case of this legislation in action is the destination resort proposed by the Thornburgh Resort Company, LLC. This resort would cover about 1,970 acres west of the City of Redmond and would require new groundwater supplies to support 1,425 dwelling units, three golf courses, two clubhouses, a community center, shops, and meeting / dining facilities.

As part of the review process, Thornburgh hired David Newton and Associates to prepare a hydrology report to inform and support Deschutes County land-use decisions about the resort. This report was released in 2005. Unfortunately, it falls far short of evaluating the impacts that pumping six proposed wells will have not only on valuable hydrological and ecological resources but also on existing wells.

2.2 Purpose

We have undertaken this study for two reasons. The first is to evaluate the impacts of the Thornburgh resort's use of groundwater. The work summarized in this report represents an effort to better understand the current hydrogeologic conditions in the UDB and to evaluate impacts to the hydrogeologic system from the proposed resort. However, an additional—equally important—goal is to demonstrate an appropriate level of evaluation that regulators should apply to any proposed developments involving new groundwater withdrawals (pumpage from new wells). We see the Thornburgh project as a case study that has a potential to establish new standards for reviewing current and future projects in the UDB. We hope these results help establish mitigation and water use strategies that sustain the Deschutes' high habitat and recreational values.

This study was authorized by Steve Munson, long-time resident of the UDB, out of his concern for the region's resources.

2.3 Scope of Investigations

Work for this study was conducted under two separate phases, by Mark Yinger Associates (MYA) and Northwest Land & Water, Inc. (NLW). MYA, the project manager, was responsible for evaluating the regional and local geology and hydrogeology. NLW analyzed water resource data and conducted groundwater flow modeling.

2.3.1 Phase I

Phase I of this study was outlined in a scope of work our team prepared to evaluate the impacts resulting from pumping large amounts of groundwater for the Thornburgh Resort. It entailed using a U.S. Geological Survey (USGS) groundwater flow model (McDonald and Harbaugh, 1988) to predict impacts to the Deschutes River and its tributaries from the proposed pumping. The proposed Thornburgh wells were incorporated into the USGS model so we could simulate conditions under a range of steady-state scenarios.

2.3.2 Phase II

The scope of work was revised under Phase II to review and assess recent hydrologic data, and to compare this data to the data used by the USGS for its 1993–1997 study. Major components of Phase II included:

- Summarizing information about water use, policy, and legislation pertinent to the UDB.
- Compiling and summarizing hydrologic data collected since 1997.
- Evaluating trends in hydrologic data—specifically, trends in parameters that can profoundly affect fish habitat: water levels, stream temperature, streamflows, climate, seepage, and groundwater use, among others.
- Using the steady-state USGS flow model "as is" to predict the effects of pumping the proposed Thornburgh wells on streamflows and groundwater levels.
- Evaluating the ecological impacts resulting from reduced streamflows and groundwater levels predicted by the modeling.

2.4 Study Area

The study area for this report, shown in **Figure 2-1**, covers the same area as the USGS modeling investigation but focuses on the geology and hydrogeology near the proposed Thornburgh resort. The USGS study area encompasses approximately 4,500 square miles of the Deschutes River drainage basin in central Oregon, which includes several major tributaries: the Little Deschutes River, Tumalo and Whychus Creeks, and the Metolius River from the west, and the Crooked River from the east.

Land-surface elevation ranges from less than 1,300 feet near Gateway in the northern part of the study area to more than 10,000 feet in the Cascades. The study area also includes the basin's major population centers, where groundwater development is most intense and resource-management questions are most urgent. These communities include Bend, Redmond, Sisters, Madras, Prineville, and La

Pine. **Figure 2-2** shows the location of the Thornburgh resort property, the proposed wells, and public and private lands.

2.5 Warranty

This work was requested by Steve Munson and completed by MYA and NLW. It was performed, and this report was prepared, in accordance with hydrogeologic practices generally accepted at this time, in this area, for the exclusive use of Steve Munson. No other warranty, express, or implied, is made.

3.0 Background Information

The UDB is presently one of the fastest growing areas in Oregon. The number of people in Deschutes County, the most populous in the basin, quadrupled between 1970 and 2001 (Gannett and Lite, 2004), and grew by about 29 percent from 2001 to 2006. Approximately 160,000 people lived in the UDB as of 2001. Growth is expected to continue, and residents and government agencies are concerned about supplying water to the growing population while protecting the rights and resources of existing water users. Surface-water resources in the area have been closed to additional appropriation for many years. Therefore, virtually all new development in the region must rely on groundwater sources.

3.1 USGS Investigation

In response to this concern, the USGS conducted an investigation of the hydrogeology of the UDB, collecting data from 1993 to 1997. Prior to the USGS study, researchers had insufficient data to quantitatively evaluate the connection between groundwater and streamflow—or even the behavior of the regional groundwater flow system in general. At the time of the USGS investigation, and prior to 2005, Oregon water law required those applying for new groundwater rights to evaluate the potential effects of groundwater development on streamflow.

The USGS investigation was born out of the hydrologic information void. The objectives of the study were to quantitatively assess the regional groundwater system and to provide analytical tools for making sound resource-management decisions. It has helped State and local government agencies, geologists, hydrologists, and residents when considering applications for new groundwater rights.

3.2 Regulatory Framework

3.2.1 Scenic Waterways Act

The *Scenic Waterways Act* was voted into law in November, 1970 to protect the free-flowing character of designated rivers for fish, wildlife and recreation and protect and enhance scenic, aesthetic, natural, recreation, scientific and fish and wildlife qualities along scenic waterways. Under this law, the portion of the Deschutes River below the Pelton Reregulation Dam to the Columbia River is classified as a Recreational River Area under the Scenic Waterway Act (OAR 736-040-0070).

In accordance with a 1988 Supreme Court Decision (Diack vs. City of Portland) the Water Resources Commission must find that scenic waterway flows will not be impaired before issuing new water rights. As originally enacted, the Oregon Scenic Waterway Act prohibited new allocation of water from scenic waterways unless the Water Resources Commission determined the use was consistent with the scenic waterway law.

3.2.2 Instream Flows Established

In 1991 the Oregon Water Resources Department (OWRD), Oregon Parks and Recreation Department, and Oregon Department of Fish and Wildlife (ODFW) established the specific flow levels needed for fish, wildlife, and recreation in the Deschutes Scenic Waterway. The State also established instream water rights to protect flows in the river system for fish and recreational values. According to the 2006 Water Summit report on instream flows (Golden and Aylward, 2006) these protected flows are already not met many months of the year for reaches in the study area. In general, irrigation storage and diversions are the primary reasons. Streamflow in the Little Deschutes River and upper Deschutes River is primarily affected by reservoir storage operations. Conversely, streamflow in the middle Deschutes River, Tumalo Creek, and Whychus Creek is affected by irrigation diversions (Golden and Aylward, 2006).

3.2.3 SB 1033 & Appeals

In 1995, the State legislature approved Senate Bill 1033, which amended Oregon's *Scenic Waterways Act*, allowing new groundwater uses that measurably reduce streamflows of scenic waterways—if mitigated. A measurable reduction is defined as 1 percent or 1 cubic foot per second (cfs), whichever is less. All new rights would be subject to the proviso that groundwater use would be curtailed if data demonstrated a negative impact to scenic waterways. A public process to develop mitigation rules was started in 1998. Based on preliminary results of the USGS study, OWRD determined there was significant potential that new groundwater use would result in reduced streamflow on scenic waterways, and therefore, in 1998, a moratorium was placed on granting new groundwater permits. Issuance of final mitigation rules occurred in September 2002.

In November 2002, WaterWatch, an advocacy group for Oregon rivers, filed a case against OWRD arguing that the mitigation rules violated the *Scenic Waterways Act* and over allocated surface water in the UDB—thus failing to protect instream water rights. In May 2005, the Court of Appeals found in favor of WaterWatch. The mitigation rules were rejected because the Court found that they allow a lessening of impact even though the law requires maintaining current flow. The Court in its opinion recognized that the legislature could choose to alter water resource policy established in statutes, opening the door for House Bill 3494.

3.2.4 House Bill 3494

In 2005, House Bill 3494 passed, authorizing allocation of groundwater whether or not it impacts the Deschutes River, regardless of the instream flows already established under the *Instream Water Rights Act*. The potential effects of groundwater development on streamflow did not need to be evaluated when considering applications for new groundwater rights. House Bill 3494 undermines Oregon's *Scenic Waterways Act*, passed in 1970 to protect flows needed for fish, wildlife, and recreation in the Deschutes and other world-class rivers in Oregon.

HB 3494 passed with a "sunset provision" of January 2, 2014. After HB 3494 sunsets, the rules found illegal by the Oregon Court of Appeals in 2005—but which became legal under HB 3494—will be terminated, precipitating the development of a new mitigation and water use strategy for the Deschutes basin.

3.2.5 Current Concerns

The sunset provision raises a number of concerns related to the long-term ecological health of the UDB. Developers now have an incentive to rush projects requiring new groundwater sources before the sunset date. Developments and associated water rights may be approved without adequate scientific investigation to quantify hydrogeologic impacts. Because development is essentially unchecked, the current and future health of the Deschutes hydrogeologic system is threatened by declining groundwater levels, spring flows, and streamflows, along with increased river water temperatures.

Although the USGS did much to characterize the hydrogeologic system of the UDB in the 1990s, development has been significant since then. As a result, trends in water use, streamflows, and groundwater levels have changed, potentially affecting the region's ecological resources.

4.0 Previous Work

Many researchers have studied water resources in the UDB. This section identifies much of the work conducted, the agency responsible for the work, and how it was used in this report. Rather than listing all work done in the UDB, we have focused on investigations that provided the most pertinent information for understanding the general history and technical hydrogeology of water resources in the UDB. A complete list of references used to prepare this report is included in Section 14.

4.1 Geology & Hydrogeology

The USGS has published many reports on different aspects of water resources in the UDB. A complete list of this work can be obtained online[1]. The work described below was the basis of the geology and hydrogeology summary in Section 5, the comparison of recent and previously available hydrologic data presented in Section 6, and the modeling efforts detailed in Section 7.

- *Groundwater and Water Chemistry Data for the Upper Deschutes Basin* (Caldwell and Truini, 1997). Presents basic data collected and compiled for the UDB, such as well log records, water levels, and water chemistry data for selected well, spring, and surface water sites.
- *Groundwater Hydrology of the Upper Deschutes Basin, Oregon* (Gannett et al., 2001). Provides a comprehensive, qualitative description of regional groundwater flow in the UDB and an analysis of the data compiled or collected for the study.
- *Geologic Framework of the Regional Groundwater Flow System in the Upper Deschutes Basin, Oregon* (Lite and Gannett, 2002). Describes the geologic structures and stratigraphic units that form the framework for the groundwater flow system in the UDB. The geology has a direct effect on the occurrence and movement of groundwater.
- *Hydrogeology of the Upper Deschutes Basin, Central Oregon: A Young Basin Adjacent to the Cascade Volcanic Arc* (Sherrod, Gannett, and Lite, 2002). Explores the visible and conceptual aspects of the regional groundwater hydrology of the UDB, including the interaction between groundwater and streams.

[1] *http://or.water.usgs.gov/proj/deschutes_gw/pubs.html*

- *Simulation of Regional Groundwater Flow in the Upper Deschutes Basin, Oregon* (Gannett and Lite, 2004). Describes the mathematical simulation of regional groundwater flow in the UDB. It includes a description of the hydrology of the UDB and the methodology for representing the hydrologic system in the numerical model. It also includes hydrologic data used for the model calibration and a description of the calibration procedures.

4.2 Other Technical Work

Other technical work has been conducted to quantify seepage in the gaining and losing reaches of the streams in the UDB, to document stream temperature, to identify critical habitat for listed fish, and to survey and document flora and fauna. This report does not discuss the flora and fauna surveys, but the reports are listed here because they comprise important technical work that has been done in the UDB.

Seepage Data (McSwain, pers. comm., 2008). Seepage measurements were made for OWRD and Bureau of Land Management (BLM). These data were used to quantify seepage in gaining and losing stream reaches as reported in Section 6.

Stream Temperature (Watershed Sciences, 2002). Continuous temperature measurements and aerial visible and infrared photographs were collected and reported for the Oregon Department of Environmental Quality (ODEQ) by Watershed Sciences. Temperature measurements were used in Section 6.

Critical Fish Habitat (USFW, 2005) and (Fies et al., 1996). Identifies critical habitat for bull trout and native redband trout; also, identifies and discusses the reintroduction of salmon and steelhead. These data were used for Section 10.

Botanical Surveys (WPN, 2006). A botanical inventory on the Middle Deschutes from Odin Falls to Culver gauge that was prepared for the BLM.

Aquatic Invertebrate Survey. A macroinvertebrate study was conducted for BLM to establish baseline conditions for comparison to data collected in the future. Invertebrate populations and diversity are indicators of stream health.

4.3 Management & Mitigation

Much work has been done towards managing water resources in the UDB. Although there is a large body of information about the legislative history of water resources in Oregon and the UDB, it is beyond the scope of this report to compile that information. However, a few crucial documents describe water resource management, and, in particular, mitigation of diminished streamflow in the UDB. They are described below.

Hydrology Report, Water Supply Development Feasibility: Proposed Thornburgh resort, Deschutes County, Oregon (Newton, 2005). Prepared for the Thornburgh destination resort, this documents reports on the feasibility of groundwater development. The Deschutes County Board of Commissioners accepted this report as an adequate demonstration of sufficient groundwater supply for the proposed project, deeming that the potential impact to groundwater levels and nearby streams is acceptable.

Deschutes Groundwater Mitigation Program, 5-Year Program Evaluation Report Draft (OWRD, 2008). Evaluates the first 5 years of the groundwater mitigation program. We used this information in Section 12.

Deschutes Basin Water Summit 2006. This conference brought together stakeholders to enroll them in a consensus process for developing a comprehensive water management plan. It communicated the findings of a number of comprehensive studies on the following topics: instream flows; growth, urbanization, and land use changes; water management scenarios; groundwater demand; irrigation district water efficiency; and reservoir management. All of these reports can be viewed from the Deschutes River Conservancy website[2]. While most of these reports were not used directly in the report, they comprise an important body of work on management strategy in the UDB. The report on instream flow was used in Section 12.

[2] *http://www.deschutesriver.org*

5.0 Geology & Hydrogeology

This section summarizes the geology and hydrogeology of the UDB and the Thornburgh resort area. This information largely based on publications of the USGS, OWRD, and the Oregon Department of Geology and Mineral Industries (DOGAMI). For additional information, consult the following references:

- *Geologic Map of the Bend 30- x 60-Minute Quadrangle, Central Oregon, USGS Geologic Investigations Series I-2683* (Sherrod et al., 2004)
- *Geologic Framework Of The Regional Groundwater Flow System In The Upper Deschutes Basin, Oregon, USGS Water Resources Investigations Report 02-4015* (Lite and Gannett, 2002)
- *Groundwater Hydrology of the Upper Deschutes Basin, Oregon, USGS Investigations Report 02-4162* (Gannett et al., 2001)
- *Hydrogeology of the Upper Deschutes Basin, Central Oregon: A Young Basin Adjacent to the Cascade Volcanic Arc, DOGAMI Special Paper 36* (Sherrod et al., 2002)
- *Groundwater Hydrology of the Upper Deschutes Basin and Its Influence on Streamflow* (Gannett et al., 2003)

A limited amount of field work was done for this study in the vicinity of Thornburgh resort.

5.1 Physiographic Setting

The UDB is the portion of the Deschutes River drainage basin upstream of Trout Creek. Trout Creek enters the Deschutes near Warm Springs, Oregon. The basin stretches from the crest of the Cascade Mountain Range east approximately 100 miles and from Trout Creek south to just north of Chemult, Oregon, a distance of approximately 100 miles. The cities of Bend and Redmond are the major population centers and are located 25 to 30 miles east of the crest of the Cascade Mountain Range and near the center of basin, north to south. The combined population of the rapidly growing cities of Bend and Redmond is approximately 102,000. The smaller cities of Prineville and Madras are located 18 miles to the east and 25 miles to the north of Redmond respectively. Their combined population is approximately 16,000. The small city of Sisters is located about 20 miles west of Redmond. The small community of Tumalo is located about 5 miles south of the Thornburgh property.

The Thornburgh resort lies approximately 6 miles west of Redmond and 2 miles west of the north-flowing Deschutes River (**Figure 2-2**). It is located on and adjacent to the Cline Buttes, which consist of three prominent buttes and a lower ridge. These features have a northeasterly trend. The buttes rise 1,000 feet above the surrounding plain. The surrounding plain generally slopes gently to the north-northeast. The Deschutes River enters a narrow, steep wall canyon just north of the community of Tumalo. East of the Cline Buttes, the river canyon is 100 to 150 feet deep.

The major tributaries of the Deschutes River are the Little Deschutes River, Metolius River, Crooked River, Fall River, Tumalo Creek, and Whychus Creek[3]. The Deschutes is dammed twice near the northern boundary of UDB, forming Lake Billy Chinook and Lake Simtustus. The mean annual flow of the Deschutes River at Bend is 378 cfs; just above Lake Billy Chinook, it is 928 cfs (Gannett et al., 2003).

Portions of three major physiographic provinces occur within the UDB. The High Cascades physiographic province along the western edge of the basin is dominated by large stratovolcanoes with summit elevations of just over 10,000 feet. The northeastern portion of the UDB includes the western end of the Blue Mountain physiographic province. This area includes the Mutton, Ochoco, and Maury Mountains and most of the Crooked River drainage basin. The southeastern portion of the UDB includes the western end of the High Lava Plains physiographic province, where the dominant feature is the large Newberry shield volcano. The central crater of this shield volcano is about 20 miles south of Bend.

5.2 Climate

Moist marine air moving eastward from the Pacific Ocean has a dominant and moderating influence on the climate of the UDB. The winters are cool and wet and the summers are warm and dry. The great majority of the annual precipitation in the UDB occurs as snow and rain along its western margin; as moisture-laden marine air rises to flow eastward up and over the crest of the Cascades, it cools, leading to large amounts precipitation. The amount of precipitation varies dramatically across the UDB—from 100 plus inches per year along the Cascade crest to less than 1 foot over much of the basin (Taylor, 1993). The 30-year average annual precipitation at Redmond is 8.6 inches (Taylor, 1993).

[3] *Whychus Creek is the new name of Squaw Creek.*

5.3 Geologic Setting

The following discussion of the regional geology is based on our literature review and on well logs. The discussion of local geology focuses on the Thornburgh destination resort area and includes observations made during field reconnaissance conducted for this study. A more detailed description of the regional geology is contained in **Appendix A** and selected water well logs for the Thornburgh area are included in **Appendix B**.

5.3.1 Regional Geology

The region has a long and complex history dominated by volcanic activity that stretches from the Eocene through the Holocene Epochs. The UDB is a depositional basin filled with lava flows and volcaniclastic material known as the Deschutes Formation, derived primarily from the Cascade Mountain range, which flanks the basin on the west. To the north and east, the volcaniclastic material of the basin fill lapped onto uplands composed of older Oligocene to Miocene volcanic material of the John Day and Clarno Formations. The John Day Formation likely underlies most of the UDB. Much of the southern portion of the basin is filled with Pleistocene to Holocene basalt lava flows of the Newberry volcano and alluvial and glacial outwash deposits of silt, sand, and gravel.

Figure 5-1 is a generalized geologic map taken from a USGS study (Gannett and Lite, 2004). The following table summarizes the stratigraphy of the region.

Geologic unit	Age	Description	Generalized Geologic Units of Figure 5-1
Sediments	Pleistocene to Holocene	Alluvium and glacial outwash silt, sand and gravel, and sands and gravels of present day streams	Quaternary sedimentary deposits
Volcanic deposits	Pleistocene	Andesite and basaltic-andesite lava flows, basalt lava flows, ash flows,	Volcanic deposits, of the Quaternary Cascades and Newberry volcano
Deschutes Formation	Late Miocene to Pliocene	Mudflows, debris flows, sandstone, conglomerate, basaltic and andesitic lavas flows, ash flows, air-fall ash and cinder cones	Volcanic and sedimentary deposits, late Tertiary and Quaternary
Volcanic and sedimentary rocks	Pliocene	Basaltic-andesite and basalt lava flows and alluvial fan deposits	
Prineville basalt	Miocene	Basalt lava flows	Prineville basalt
John Day Formation	Oligocene to late Miocene	Altered andesitic ash flows, air-fall tuffs, tufaceous sediments, rhyolite domes, and andesite and basalt lava flows	Early Tertiary volcanic deposits
Clarno Formation	Eocene	Altered andesitic lava flows, ash flows, mudflows, tuffaceous sediments, mudstone, claystone, siltstone and conglomerate	

5.3.2 Local Geology

The Thornburgh property is located on, and in the immediate vicinity of, Cline Buttes, a rhyolite dome complex that rises approximately 1,000 feet above the surrounding plain, which consists of basalt and basaltic-andesite lava flows of the Deschutes Formation (**Figure 5-2**). These flows overlie sandstones and conglomerates of the Deschutes Formation. The thickness of the overlying lava flows is quite variable, ranging from 40 feet to as much as 300 feet.

The bulk of Cline Buttes consists of devitrified, light-tan, sparsely porphyritic rhyolite with very faint to no discernible flow banding, a sugary texture with brownish clots of iron oxides, and an irregular tight fracture. Other textures include spherulitic in combination with faint flow banding. The rhyolite dome complex and contemporaneous basalt lava flows suggest a strongly bimodal basalt-rhyolite magma (Streck and Grunder, 2007).

A low ridge extending to the southwest of the highest butte is likely a rhyolite lava flow or flows that may have buried older vents. The ridge consists of tan to light-gray rhyolite with distinct, fine, and generally planar flow banding having a platy fracture coincident with flow bands. The platy fractures are generally tight. Two linear zones of intense siliceous alteration were observed. They appear to be associated with southwest-trending fracture zones. Here the flow-banded rhyolite is completely replaced with massive, pure white, very-fine-grained silica.

A large rock quarry on the east side of the northern butte cuts into the flank of the butte, exposing distinct zones of rhyolite breccia. A long bulldozer-cut near the top of the quarry exposes at least four distinct zones of autoclastic breccia. The breccia and hydrothermal alteration zones dip steeply away from the dome summit. The intensity of brecciation and degree of alteration increases outward from the dome core. Each zone likely represents an episode of movement and hydrothermal alteration associated with a pulse of magma moving into the vent and pushing upward and outward. The outer breccia zones of the dome have undergone repeated episodes of fracturing and fracture surfaces are commonly coated with brown clay or silica, the products of hydrothermal alteration. The lower portion of the quarry, at the base of the slope, cuts across an apron of rubble. The material comprising the apron is a complex assemblage of angular, broken rhyolite shed off the steep upper slopes the dome, tephra, agglomerate, and lavas. The lavas are discontinuous and very broken, consisting of flow-banded gray and reddish-gray rhyolite and flow-banded obsidian. The volcanic rubble of the apron is loose to weakly cemented with silica and very porous. Locally, the material has undergone intense siliceous alteration, a process that has greatly reduced its permeability. The debris apron of the dome complex is, to a large extent, buried beneath Quaternary colluvium and alluvial fan deposits. Paleo-tributaries of the

Deschutes River that flowed northeast may have eroded away significant portions of the debris apron along both the southeast and northwest sides of the buttes.

In the rock quarry, three areas of loose or very weakly cemented spherulites (4–10 mm) were observed in areas near the contact between the debris apron and rhyolite breccia. The spherulites may be the residual of intense and localized hydrothermal alteration of the chilled glassy margin of the rhyolite.

Relatively little is known about the subsurface in the vicinity of the Cline Buttes rhyolite dome complex. The rhyolite has an isotopic age of 6.14±0.20 Ma (million years ago; Sherrod et al., 2004). The complex is generally contemporaneous with the surrounding Deschutes Formation, which consists of basalt and basaltic-andesite lava flows and volcaniclastic sedimentary rocks. Driller's logs for the six water wells located nearest the dome complex (DESC 756, 952, 1198, 3666, 3669 and 54485) were examined (**Appendix B, Figure 5-2**). Well DESC 756, located on the south slope of the highest butte at about 3,350 feet in elevation, may intersect as much as 830 feet of rhyolite. The driller describes a hard, brown sandstone, possibly misidentifying devitrified rhyolite as sandstone because of its sandy or grainy texture and flow banding. The driller of well DESC 3669, located about a half mile to the south at approximately 3,160 feet in elevation, describes hard brown and gray rock and sandstone to 496 feet beneath the surface and then water-bearing sand and gravel from 496 feet to 535 feet beneath the surface. The other four wells do not appear to intersect the rhyolite based on the well logs. A well (DESC 1198) just north of the dome complex may intersect the dome debris apron.

5.4 Hydrogeologic Setting

The discussion the regional hydrogeologic setting is largely based on the USGS study *Geologic Framework of the Regional Groundwater Flow System in the Upper Deschutes Basin* (Lite and Gannett, 2002).

5.4.1 Regional Hydrogeology

The USGS study identified several hydrogeologic units, as shown on **Figure 5-3**. A hydrogeologic unit may consist of a single geologic unit with distinct hydraulic properties or portions of one or more geologic units grouped together because of similar hydraulic properties.

The following table summarizes the hydrogeologic units of the UDB. Additional description of the regional hydrogeology is included in **Appendix A**.

Hydrogeologic Unit	Description
Quaternary sediments	Unconsolidated silt, sand and gravel, low to moderately permeability
Cascade and Newberry volcanic deposits	Fractured lava flows and tephra, moderately to very permeable
Inactive margin deposits	Fine grained sediment facies of the Deschutes Formation deposited along the eastern edge of the basin, low permeability
Ancestral Deschutes River channel deposits	Coarse sand, gravels and intra-canyon lava flows, ancient Deschutes River channel deposit facies of the Deschutes Formation, very permeable
Proximal deposits	Fractured lava flows, flow breccias and coarse tephra facies of the Deschutes Formation, moderately permeable
Arc-adjacent alluvial plain deposits	Fractured lava flows, sandstone and conglomerate facies of the Deschutes Formation, moderately to very permeable
Pre- Deschutes Formation deposits	Pervasively altered volcanic and volcaniclastic deposits of the John Day Formation, includes hydrothermally altered rock at depth beneath the Cascades and Newberry volcano, very low permeability

The Deschutes Formation is the primary aquifer in the UDB. It has been subdivided into four hydrogeologic units. These units generally relate to the source of material deposited and the depositional environment.

5.4.2 Local Hydrogeology

The Deschutes Formation is also the primary aquifer in the Cline Buttes and Thornburgh resort area. The nearest large-capacity wells are those of the Eagle Crest destination resort, located about 1 mile east of Cline Buttes. They appear to produce water from Deschutes Formation sandstone beneath basalt flows—reportedly 300 to 500 gallons per minute (gpm). One Eagle Crest well (DESC 54485, **Appendix B**) located about a half mile north of the northern butte penetrates, starting at the surface, 242 feet of basalt, then 360 feet of "multi-colored rock," and then confined water in sandstone (**Figure 5-2**). The multicolored rock that varies from soft to hard may be material of the rhyolite dome's debris apron. Wells (DESC 9358 and 9359) in the Crest Ridge development, about 2 miles northeast of the northern butte, produce over 100 gpm from Deschutes Formation sandstone.

Few wells appear to intersect the rhyolite dome complex. DESC 756, located up the south slope of the tallest butte, is the highest elevation well in the area (**Figure 5-2**). This well appears to penetrate 550 to 830 feet of rhyolite and produces 10 gpm from a fractured lava at 830 to 880 feet beneath the surface. The water in the fractured lava is confined, rising 100 feet above the top of the fractured lava, indicating that the rhyolite is impermeable. An Eagle Crest well (DESC 1083), located along Cline Falls Highway about a mile east the summit of the buttes, penetrates lavas and "rock" to 460 feet and then from 460 to 800 feet brown and gray "andesite" variably described as soft, hard, and weathered. The andesite described by the driller may be rhyolite. This well produced only 30 gpm. Wells one-half mile farther east encounter water-bearing Deschutes Formation sandstone at shallower depths.

The permeability of the Cline Butte rhyolite is likely significantly lower than that of surrounding volcaniclastic sedimentary rocks. Repeated episodes of argillic and siliceous hydrothermal alteration have filled fractures, reducing its initial fracture-dependent porosity and permeability. A zone of argillic and siliceous alteration is also likely to extend into the surrounding volcaniclastic sedimentary rocks, reducing their original permeability. It has been stated that the rhyolite of Cline Butte and the rhyodacite lava flows near Steelhead Falls (approximately 8 miles north) are more permeable than the surrounding material (Sherrod et al., 2002; Gannett et al., 2001). There is good evidence to support this statement for the rhyodacite lava flows of Steelhead Falls, but not for the hydrothermally altered rhyolite of Cline Buttes. Water levels in wells that penetrate the sandstones and conglomerates around Cline Buttes are higher on the south/southeast side (the upgradient side of the buttes), and lower by approximately 100 feet on the northwest side. This is what would be expected if the rhyolite represented a zone of significantly lower hydraulic conductivity. If the rhyolite of Cline Buttes were much more permeable than the surrounding volcaniclastic sedimentary rocks, the groundwater gradient would be much flatter across the dome complex; however, this is not the case.

In contrast, what remains of the debris apron around the dome complex will have a much higher permeability than the rhyolite and, to a lesser degree, than the sandstone and conglomerate. Because of the very sparse subsurface data in the area, it is impossible to reliably estimate the extent of the debris apron and its extent of saturation. We suspect the debris apron is limited in its lateral extent.

5.4.3 Hydrogeologic Units & Hydraulic Properties

In this study, we use the USGS groundwater flow model for the UDB to simulate the stress of the pumping of the wells proposed for the Thornburgh destination resort. The USGS defined a set of hydrogeologic units and used them to inform the distribution of hydraulic properties within the flow model (Gannett and Lite, 2004). **Figures 5-1** and **5-3** show the USGS units, which include:

- Quaternary sediments
- Quaternary volcanic deposits of the High Cascades and Newberry Volcano
- The four facies of the Deschutes Formation consisting of arc-adjacent alluvial plain deposits
- Inactive margin deposits

- Ancestral Deschutes River channel deposits
- Proximal deposits
- Pre – Deschutes Formation rocks

Because of the lack of subsurface geologic data and the heterogeneous character of the hydrogeologic units, hydraulic properties were not assigned to each unit. Rather, the modelers considered the characteristics of the units in combination with other data to define the distribution of hydraulic properties. This data included aquifer tests, drillers' logs, specific-capacity tests, groundwater level measurements, and published data specific to the basin or considered typical or representative of the lithologies present in the basin. Gannet and Lite (2004) describe how they derived the horizontal and vertical hydraulic conductivities and storage coefficients for the model.

5.4.4 Spatial Variability

The Deschutes Formation is a complex hydrogeologic unit consisting of many rock types; therefore, its hydraulic properties are expected to vary significantly, both laterally and vertically. Preferred groundwater flow paths are formed by the lava flows and coarse sand-and-gravel channel deposits that filled paleochannels and canyons that crossed the depositional basin. These coarse sandstones, conglomerates, and fractured intra-canyon lava flows have very high permeabilities. The Pelton basalt and the Opal Springs basalt of the Deschutes Formation are very permeable lava flows that filled paleocanyons cut by the ancestral Deschutes River (Lite and Gannett, 2002).

5.5 Groundwater Flow System

5.5.1 Regional Recharge & Discharge Patterns

Groundwater flow patterns in the UDB are well documented in USGS studies (Gannett et al., 2001; Lite and Gannett, 2002; Gannett and Lite, 2004). Groundwater flows from the region's primary recharge areas — the High Cascades and Newberry volcano — in a northeasterly to northerly direction. These recharge areas receive the great majority of precipitation in the UDB, and the young, relatively unweathered volcanic deposits of these areas are very permeable, allowing rapid infiltration. The average annual recharge for the basin from 1993 to 1995 was approximately 3,500 cfs (Gannett et al., 2001).

The first large discharges of groundwater occur along the lower slopes of the Cascades to spring-fed streams. These include the upper Deschutes River, above Wickiup Reservoir, Fall River, Spring River, and the upper Metolius River. Some segments of the Deschutes River between Sunriver and Bend gain water from groundwater discharges; others lose water. However, gains significantly exceed losses. In the Bend area, water is diverted from the Deschutes River into unlined irrigation canals that extend to north of Madras. The canals that leak at the greatest rate are located in the Bend area and to the north and east of Bend. For the year 1994, leakage from canals was estimated at 490 cfs—about 46 percent of the water diverted into the canals (Gannett et al., 2001).

From Bend downstream to the Lower Bridge area the Deschutes River has both reaches with small gains and small losses, and the flows varied from 29 to 44 cfs (Gannett, 2001). Between Lower Bridge and Whychus Creek, the river begins to gain from spring discharges, however there are reaches with small gains and reaches with small losses (McSwain, 2007). Seepage along this section of the Deschutes is discussed in more detail in Section 6. From approximately Lower Bridge north to Lake Billy Chinook, the Deschutes gains about 390 cfs from groundwater discharge. The lower Crooked River gains about 1,100 cfs. Groundwater discharge to Lake Billy Chinook is estimated at 420 cfs. This large discharge of groundwater in the confluence area occurs because the permeable Deschutes Formation thins against the relatively impermeable John Day Formation as it nears the surface and eventually outcrops in the Deschutes canyon 10 miles north of Lake Billy Chinook (Gannett et al., 2001).

5.5.2 Proposed Resort Area

In the Thornburgh resort area, groundwater flows in a northwesterly direction. The groundwater elevation in Deschutes Formation wells is generally 2,700 to 2,750 feet on the southeast side of Cline Buttes and about 2,600 feet on the northwest side (**Figure 5-2**). This drop of 100 to 130 feet over a distance of about 3.5 miles is significantly steeper than the regional gradient indicated by the USGS study (Gannett and Lite, 2004).

Hydrothermal alteration associated with the rhyolite dome complex and its volcanic conduits likely has reduced the permeability of the rhyolite and adjacent Deschutes Formation volcaniclastic sedimentary rocks. In contrast, a debris apron around the dome complex consisting of broken rock shed off the steep flanks of the domes, tephra, and very broken lavas and agglomerate is likely significantly more permeable than the either the rhyolite or the rocks of the Deschutes Formation.

There are extensive irrigation canal networks approximately 2.5 miles south of the Cline Buttes and along the east side of the Deschutes River from Bend to about six miles north of Redmond. In these areas, leakage from canals and irrigation water lost to deep percolation recharges groundwater. A very small portion of the canal leakage discharges to the middle Deschutes River. From just north of Bend to Odin Falls, approximately 4 miles north of Cline Buttes, the estimated gain to the Deschutes River is only 6.5 cfs and this gain has been attributed to return flow from leaky irrigation canals (Gannett et al., 2001).

6.0 Recent Hydrologic Data

The USGS study reported precipitation, groundwater level, streamflow, and water use data. For this study, we compiled recent data and compared it to the USGS data. This section describes the result of this comparison and summarizes stream temperature and habitat data. Discussion of how trends in recent hydrologic data may impact water resources is discussed in Section 12.

6.1 Precipitation

Precipitation is the source of groundwater recharge. Since groundwater feeds parts of the Deschutes River, any reductions in recharge eventually translate to reduced streamflows, which can affect stream temperature and fish habitat. Recharge can be profoundly affected by climate change, which can decrease either the amount or duration of snow pack or the amount of precipitation that infiltrates into aquifers.

The USGS used precipitation data for the years 1993 to 1995 to calculate groundwater recharge for its regional model. This data was obtained from six sites in the UDB. For this study, we examined precipitation data from water year 1990 through 2007 for the same six sites.

6.1.1 Data Source

Precipitation data is maintained by the Western Regional Climate Center (WRCC) at the Desert Research Institute in Las Vegas. Data is available for purchase by internet download[4]. Data for the six sites used by the USGS was purchased from the WRCC for the period 1990 to 2007. These sites are shown on **Figure 6-1.**

6.1.2 Method

Data include maximum, minimum, and average temperature; total precipitation; precipitation, snowfall, snow depth, and date. Data were compiled in an Access

[4] *http://www.wrcc.dri.edu*

database and a "water year"—the 12-month period from October 1 through September 30—was assigned to each date.[5]

Total precipitation was summarized for water years 1991 through 2007 at each of the six sites. Snowfall data was summarized for Wickiup Dam, the site with highest elevation, to help assess trends in the snow pack that recharges groundwater and provides surface runoff to streams. **Table 6-1** summarizes annual precipitation at the six sites; **Figure 6-2** shows annual precipitation trends. **Figure 6-3** shows the number of days per water year with snow pack greater than 0 inches at Wickiup Dam.

6.1.3 Results

In general, the recent data indicate significantly less precipitation than the 1993–1995 data, the period used for the USGS model. The data for Wickiup Dam suggests that climate change may be reducing snow pack, but it is inconclusive.

6.2 Groundwater Levels

Groundwater levels were monitored throughout the basin and reported by the USGS for over 85 wells (Caldwell and Truini, 1997). The OWRD continued to monitor groundwater levels in 14 wells throughout the UDB (Gannett and Lite, 2001). Of these, about eight are in the vicinity of the proposed Thornburgh development and were considered in this section; these well locations are shown on **Figure 6-1**. The data was downloaded from the OWRD website and used to prepare water-level hydrographs. The long-term water level hydrographs were then reviewed, and recent trends data were compared to trends discussed by USGS (Gannett et al., 2001).

6.2.1 Data Sources & Methods

The locations of OWRD observation wells in the vicinity of the proposed Thornburgh development were identified using GIS data. The shape file, *wells.shp*, was

[5] *The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1992, is the 1992 water year.*

obtained from the OWRD website[6]. All available water level data for the Deschutes basin was obtained from OWRD[7].

Sixteen observation wells were identified in the vicinity of Thornburgh. Eight of these wells were included in the OWRD water-level database and were evaluated for this report (**Figure 6-1**). Hydrographs for these wells are shown on **Figures 6-4** through **6-12**.

Although each observation well has a different period of record, the same time scale was used for each hydrograph to compare trends. The longest period of record, 1972–present, was used for each hydrograph. Each hydrograph includes the OWRD well name (a number preceded by DESC, the identifier for Deschutes County). The well's depth and its corresponding USGS identifier are noted parenthetically if the data was included in the database.

6.2.2 Discussion

The USGS investigation of hydrology of the UDB (Gannett et al., 2001) reports that, in general, large-scale water-level fluctuations reflect responses to weather patterns. Groundwater levels rise after periods of high precipitation and decline in response to drought conditions. The USGS modeling report (Gannett and Lite, 2004) cites the 2001 report:

> *"There is no evidence to suggest that the regional groundwater system in the UDB is not in long-term equilibrium with the natural climate cycles and human activity. For example, no long-term water level declines due to pumping were observed in the data, and (with few exceptions) groundwater discharge measurements show trends that can be related only to climate."*

This conclusion is based on hydrographs presented in the USGS report (Truini, 1997), which show cyclic water-level trends with rising and declining limbs lasting no more than about 5 to 7 years and complete cycle durations lasting about a decade. Although the USGS conclusions may be correct for the observed period, they may not reflect current conditions, which are likely affected by factors other than climate. The hydrographs for the wells near the Thornburgh project have presented an opportunity to revisit old data and to assess recent trends by incorporating new data that has been collected over the last decade.

[6] *http://www.wrd.state.or.us/OWRD/GW/well_data.shtml*

[7] *http://www1.wrd.state.or.us/groundwater/obswells/data/owrd_wls.txt*

6.2.3 Results

Two hydrographs show cyclic trends and five show a declining trend since 1993. Two show a difference between older and recent data that appears inconsistent with cyclic trends, but data between the two periods is missing. These trends are detailed in the next few sections of this report. In addition, data collected since 1997 suggest that some observation wells reflect declining water level trends that are inconsistent with the decadal trends resulting from climate variation.

6.2.3.1 Declining Water Level Trends

Figures 6-4 through **6-8** (wells DESC 3903, 3949, 3581, 8626, 1957) are hydrographs that show consistent declining trends since about 1994. DESC 3903 (**Figure 6-4**) has the longest period of record, from 1972 to about 1994, and shows fluctuating water levels typical of the decadal trends that reflect climate variation until about 1994. During this period, the maximum change in water level is less than about 10 feet. However, after 1994, water levels continue to decline for 12 years, with a slight flattening from 1996 to 2002. This pattern differs from the previous 22 years. **Figure 6-5** (DESC 3949) has limited early data, in about 1979, and then a complete record from about 1993 through 2007. Because of this large hiatus, the trend between 1980 and 1994 is unclear. However, it is clear that there is a consistent downward trend from 1993 through 2006, with a flattening between about 1997 and 2003, similar to DESC 3903.

The declining trend in these observation wells is inconsistent with a cyclic pattern, suggesting that water levels may be responding to other factors. The water level decline is likely a response to not only climate change but also to groundwater pumping at rates in excess of the recharge rate.

6.2.3.2 Cyclic Water Level Trends

Figure 6-9 (DESC 3193), **Figure 6-10** (DESC 3614), and the early parts of **Figures 6-4** and **6-8** show cyclic water level trends. In these wells, water level fluctuates up and down. Each period of rise or fall lasts for 3 to 6 or more years; each cycle lasts approximately 10 years. The maximum and minimum values follow a flat trend, hovering around a consistent water level. This pattern is typical for wells that respond to the cyclic fluctuations of climate, with decreasing trends corresponding to periods of drought and increasing trends corresponding to particularly wet years.

6.2.3.3 Differences between Older & Recent Data

Figures 6-11 and **6-12** (DESC 53714 and 386) have insufficient data to establish a clear trend. However, recent water levels are significantly lower in both wells than they were during the early period of record. For **Figure 6-11** (DESC 53714), the data from about 1995 to 2005 suggests a cyclic or slight decline, but water levels during the entire 10-year period are more than 16 feet lower than they were from about 1990. Similarly, for DESC 386, the data point from 1995 is more than 10 feet lower than the data point in 1975. **Figures 6-5 and 6-8** also exhibit a significant difference between older data collected from 1978-1980 and recent data; the early data does not fit as part of the trend of the later data, but can only be explained by a declining trend.

6.3 Streamflow

The USGS reported streamflow data for the UDB available through 1997 (Gannett et al., 2001) and used the data to develop the groundwater flow model (Gannett and Lite, 2004). For this investigation, we compiled data available through water year 2007 for selected streams. These hydrographs are presented in this section. They provide current information and show the dramatic increase in streamflow between the headwaters of the Deschutes River and locations downgradient near Madras. Stream-gauging sites were selected based on data availability and location.

Figure 6-13 shows the map of stream-gauging stations from the 2001 USGS report. Stations with data presented in this report are circled. Data from two stations on the Deschutes River— Lower Bridge near Terrebon and Cline Falls—are included in this report but not covered in the USGS report. Although these stations have limited data, we have included them because their locations are important to understanding the groundwater flow system.

6.3.1 Data Source & Methods

Tabular electronic streamflow data was provided by either the Oregon Water Resources Department or the USGS[8].

Hydrographs were plotted for the 11 selected gauging stations. **Figures 6-14** through **6-24** are presented in order from upgradient to downgradient. Stations

[8] *http://www1.wrd.state.or.us/cgi-bin/choose_gage.pl?huc=17070301*
http://waterdata.usgs.gov/nwis/sw

were selected to show the change in streamflow of the Deschutes River as distance away from the headwaters increases. Stations on tributaries Whychus Creek and Tumalo Creek were included because they contain important fish resources near the proposed Thornburgh project.

6.3.2 Discussion

Hydrographs for all the gauging stations show a dramatic difference between the high flows of winter/spring and low flows of summer/early fall. In general, the low-flow conditions represent summer/early fall *baseflow*, when the stream is fed primarily by groundwater. High flow conditions occur when the stream is fed by groundwater, precipitation runoff, and/or snowmelt. Each hydrograph shows that baseflow dominates total streamflow beginning in about May and reaches its lowest flow in August or September. The relative impact of declining groundwater levels is significantly greater under baseflow conditions than under higher flows; therefore, this discussion focuses on the baseflow conditions shown in the hydrographs.

Gauging stations at Crescent Creek, Deschutes below Wickiup, and Little Deschutes at La Pine (**Figures 6-14, 6-15,** and **6-16**) represent streamflow in the most upgradient portion of the basin. Baseflow at these sites is commonly about 20–30 cfs at Deschutes below Wickiup, 5–10 cfs at Crescent Creek, and 30–60 cfs at Little Deschutes near La Pine. Gauging stations on the Deschutes at Benham Falls, Bend, Cline Falls, Lower Bridge, near Culver, and near Madras illustrate how flows increase with distance in the downgradient direction. Low-flow conditions are commonly about 500 cfs at Benham Falls, 40–85 cfs near Bend, 40–10 cfs near Lower Bridge, 500 cfs near Culver, and 3,500–3,800 cfs near Madras.

This trend shows that the most dramatic increase in groundwater discharge to the Deschutes River—about 3,000 cfs—occurs between Culver and Madras. Although baseflow increases from less than 50 cfs at the most upgradient gauging stations to 500 cfs at Culver, it decreases by about 400 cfs as it moves downgradient from Benham Falls (about 500 cfs) to near Bend (about 100 cfs). Because the data for the Deschutes at Cline Falls is old, no direct comparison to nearby gauging stations is possible. Likewise, the data record for Lower Bridge is relatively short, but its hydrograph is consistent with low baseflow conditions for Deschutes at Bend.

Gannett and Lite (2001) report that the most substantial stream losses measured in the basin occur on the Deschutes River between Benham Falls and Bend. Stage and flow rate in this reach is reported to be controlled by reservoir operations upstream. Gannett and Lite report that streamflow is highest from April to October, when water is released from reservoirs for canal diversions near Bend. However, Gannett and Lite (2004) acknowledge that there is a losing reach between Benham Falls and Bend, reporting losses of about 90 cfs, based on a long-term data record (1945–1995); this is likely due to irrigation diversions.

The hydrograph for the Deschutes at Benham Falls shows high flows during the typical low-flow season, from about May to early October. At Bend, high flow occurs during the wet season, from late fall through spring. Streamflow at Benham Falls is affected by reservoir operations, while streamflow at Bend is affected by irrigation diversions. Regardless of the reason, baseflow in the Deschutes River from Bend to Lower Bridge is the lowest flow in the middle Deschutes River and is about 100 cfs.

6.4 Groundwater Use

Monthly pumping data from both public and large private water supply purveyors was summarized for 1997 through 2006. This data was then compared to usage during the period of record for the USGS groundwater flow model (Gannett and Lite, 2004).

6.4.1 Data Sources & Methods

Groundwater use data for public systems from 1997 through 2006 was acquired from an OWRD online database[9]. We also obtained from OWRD water use data for private systems in the central portion of the UDB. Data was provided in electronic format and is generally reported in million gallons (MGals). Some water purveyors report water use in cubic feet; these data were converted to MGals.

Pumping records were entered into an Excel spreadsheet and compiled into an Access database. **Appendix C** summarizes public and private water use data. **Table C-1** lists monthly water use for each year for each public supply well included in this analysis; **Table C-2** lists monthly water use for each private supply well. **Tables 6-2** and **6-3** summarize the total combined monthly and annual water use for public and private wells, respectively. **Tables 6-4** and **6-5** are for public and private wells, respectively, and summarize the annual water use for each well, making it easy to see trends and identify data gaps[10].

[9] *http://www.wrd.state.or.us/OWRD/WR/water_use_report.shtml*

[10] *Although pumpage was reported, it was never entered into OWRD's database because of resource constraints.*

Because the missing data affects the annual totals, we had to estimate pumpage to assess trends in public water use. For example, **Table 6-2** indicates that pumping from public supply wells was 2,546 MGals in 2006 and 3,533 MGals in 2005. However, **Table 6-4** indicates that data is missing for 12 wells in 2006, even though pumping occurred. If 2005 pumpage values were applied to the missing 2006 data, **Table 6-2** would show 3,891 MGals instead of 2,546. Similarly for 2004, data was not reported for 19 wells. If 2003 values were applied to 2004, annual water use would be 4,796 MGals, instead of the 1,642 shown on **Table 6-2**.

6.4.2 Results

Tables 6-2 and **6-3** show that public and private water use has increased significantly since 1997, and that it differs from the estimates in the USGS model, which used 31 cfs, or 7,369 million gallons per year (MGY) for pumping from public supply and irrigation wells. Trends in public and private water use show a combined increase of as much as 4,000 MGY (17.0 cfs) since 1997.

6.5 Seepage Data

Seepage data provides important information about the relationship between a stream and the adjacent groundwater system. In areas where the stream elevation lies above the water table, water seeps from the stream into the aquifer along a "losing" reach. Conversely, where the stream elevation is below the water table, water seeps from the aquifer system into the stream along a "gaining" reach. Consequently, when groundwater levels decline along gaining reaches, streamflow also declines. Along losing stream reaches, seepage to the underlying aquifer increases, provided the stream is not perched above the aquifer.

Seepage can be estimated by measuring streamflows at points located a few to several miles apart over a relatively short period. Other factors are considered in developing seepage estimates, including reach length, diversions, and tributary inflows. Because seepage data is collected over a relatively short period, it represents a snapshot of both the rate and distribution of groundwater inflow to, or leakage from, a stream.

Seepage runs conducted by the OWRD in the UDB are reported by the USGS (Gannett and Lite, 2001). More recently, the OWRD and BLM have measured seepage. This section of the report discusses recent data, which were analyzed and compared to results reported by the USGS in 2001.

6.5.1 Data Sources & Method

The results of seepage runs conducted by the OWRD during the period from 1992 to 1994 are reported by the USGS (Gannett and Lite, 2001). The BLM contracted with the USGS to collect seepage data on July 12, 2005, at seven sites from Deschutes River below Bend to near Culver; this data was provided to us on a CD (McSwain, pers. comm., 2008). The OWRD collected seepage data on August 3 and 4, 2005. This preliminary data was provided in the form of an Excel spreadsheet (McSwain, pers. comm., 2008). **Appendix D** contains tabulated seepage data from each of these sources.

The recent BLM and OWRD data were compared and appeared consistent with each other. Because the BLM data does not include tributary discharge measurements, gains at Deschutes below Whychus Creek could not be fairly compared. Therefore, the OWRD data set was analyzed for this study because it was larger. Reach length was calculated as the difference in river miles between measurement locations. Seepage rate along a stream reach between two adjacent measurement sites was calculated by subtracting the upgradient measurement and tributary inflow (if any) from the downgradient measurement. The seepage rate per river mile was calculated by dividing the total reach seepage by the reach length.

We used ArcMap, a geographic information system, to map the seepage measurement points and identify them by river mile (RM), as shown on **Figure 6-25**. The site description that corresponds to the river mile is included in the table in **Appendix D**. **Figure 6-25** shows the calculated seepage rate between each designated river mile using a color-coded gain/loss value; total seepage per stream reach is also noted.

6.5.2 Results

Figure 6-25 indicates that minimal groundwater inflow occurs into the Deschutes River between Bend (RM 164) and Lower Bridge (RM 134). The Deschutes gains flow from Lower Bridge to RM 128.7, and then loses some flow again from RM 128.7 to RM 126.1. Gains are then mild from RM 126.1 to RM 124.9, strong from RM 124.9 to RM 123.3, and mild to RM 120 near Culver. Downgradient from Culver, the Deschutes gains strongly, as shown by the streamflow hydrographs between Culver and Madras. These gains and losses are important to understanding how declining groundwater levels may affect flows to or from a particular reach.

The USGS reports discharge measurements at 19 stations along the Deschutes River from Bend to Culver (Table 5; Gannett and Lite, 2001). These measurements were used to estimate gains or losses for larger stream reaches that extend over many stations. Color is used to indicate the seepage rate per RM, and a number indicates the total gain or loss along a reach (Table 7 and Figure 12; Gannett and Lite, 2001). Although this map shows general patterns of groundwater inflow to streams in the UDB, it may be misleading because combining the individual measurements results in a loss of important detail. For example, the reach from RM 130.5 to RM 120 combines results for seven sub-reaches and indicates significant inflow of 305 cfs. However, of the seven sub-reaches, two have significant inflow, one is losing, one has zero inflow, and three have mild inflow of less than 20 cfs. This breakdown is similar for the OWRD data, except that two of the sub-reaches were losing in 2005.

Figure 6-25 shows that the reach sections in the vicinity of Thornburgh, between Bend and Whychus Creek, are characterized by both losing and gaining conditions. Most of these sections have relatively small gains or losses; only a few short sections have significant inflow rate. It is likely that within a river section characterized by a "loss" there are sub-sections within it where gains, or inflow, occurs.

6.6 Stream Temperature

Stream temperature, a critical factor in fish viability, provides useful information about seepage into a stream[11]. Groundwater inflow to streams can be identified from a temperature profile. Groundwater has a relatively constant temperature that is cooler than the water in streams—particularly in the summer, during low-flow conditions, when consistent groundwater inflow is critical. Conversely, where groundwater inflow does not occur, stream temperature increases down-gradient.

Thermal infrared (TIR) remote sensing, a reliable method for measuring stream temperature, was used to survey selected streams in the UDB in late July 2001. The survey was conducted for ODEQ, and the TIR results reported in *Aerial Surveys in the Deschutes River Basin — Thermal Infrared and Color Videography* (Watershed Sciences, 2002).

6.6.1 Data Source & Method

A complete set of project data and a report was provided by ODEQ. This data was mapped using ArcMap as shown on **Figure 6-26**.

[11] *Stream temperatures below 15°C are required for bull trout habitat.*

6.6.2 Discussion

This discussion describes the general temperature distribution and focuses on Whychus Creek and the part of the Deschutes near the Thornburgh resort.

Stream temperature ranged from 3.5 to 28.0°C during the temperature survey in July 2001. In general, cool stream temperatures—below 14°C—occur mostly at higher elevations along the headwaters of tributaries to the Deschutes, in the uppermost reaches of the Deschutes, and throughout most of the Metolius. The warmest stream temperature, over 26°C, occurs in Whychus Creek and in the Deschutes just downstream from Redmond.

In general, temperatures increase gradually as the stream flows downgradient; abrupt temperature decreases occur periodically. The temperature distribution along the stream reaches shown in **Figure 6-26** is consistent with the seepage data (**Figure 6-25**). Abrupt temperature decreases correspond to locations where stream inflow from groundwater is moderate to significant. From its cool headwaters, the Deschutes increases in temperature as it flows downstream and hovers between 14° and 18°C until a few miles upgradient from Bend. From above Bend, temperature continues to increase to as much as 26°C and exceeds 22°C for most of the reach from Bend to about RM 130. Little change occurs until about RM 134, where temperature starts to decrease slightly but stays above 20°C. This first slight decrease corresponds to the location of the first reach with moderate groundwater inflow. Temperature decreases significantly, to below 16°C, downgradient from RM 130.5, where significant inflow occurs (**Figure 6-25**). Temperature increases again to more than 19°C until about RM 124, and then decreases abruptly, falling to about 15°C at the confluence with Whychus Creek. This decrease corresponds to the reach with the largest groundwater inflow. Stream temperature increases again as the Deschutes flows downstream from Whychus Creek and then stays at about 17°C, until the endpoint of the temperature survey on the Deschutes River, RM 120.

In Whychus Creek, temperature is below 14°C from its headwaters to just upstream from Sisters; temperature continues to increase from Sisters, reaching over 26°C for several miles. Whychus Creek starts to cool significantly at about 2 miles upstream from the confluence with the Deschutes. It is likely that the hydrogeologic conditions that cause strong groundwater inflow to the Deschutes near the confluence with Whychus Creek also cause this significant decrease in temperature.

Temperatures in the Deschutes River, near the Thornburgh resort, and in Whychus Creek upstream of Alder Springs (about two miles above its confluence with the Deschutes) are relatively high, exceeding by more than 10°C the optimal maximum of 15°C for bull and native redband trout. It is apparent from **Figures**

6-25 and **6-26** that groundwater inflow is critical to maintaining cool stream temperatures.

7.0 Groundwater Flow Modeling

The USGS modeling report (Gannett and Lite, 2004) states,

> *"In the Upper Deschutes Basin, the principal source of water to pumped wells once equilibrium has been attained is diminished streamflow."*

We used the USGS model, with a few modifications, to evaluate the magnitude and distribution of impacts resulting from pumping the proposed Thornburgh wells. It predicts affects on streamflow in specific reaches of the Deschutes River and Whychus Creek, and on groundwater levels in the proposed project vicinity. These reaches on the Deschutes River include Bend to RM 149 and Odin Falls to Whychus Creek, and the lower part of Whychus Creek.

This section describes our model simulations and results. Groundwater Vistas™ (version 5) was used to run the MODFLOW simulations conducted to evaluate potential impact of groundwater withdrawal from the proposed Thornburgh wells. Groundwater Vistas, developed by Jim Rumbaugh of Environmental Simulations, Inc., is a graphical user interface for three-dimensional flow- modeling software that allows users to prepare input files, run MODFLOW with a variety of solvers including ModSURFACT™, and process output files. ModSURFACT uses MODFLOW code with a proprietary solver developed by HydroLogic.

7.1 Description of the USGS Model

The original USGS groundwater flow model for the UDB is described here briefly. For more details, refer to the modeling report (Gannett and Lite, 2004), which contains detailed descriptions and maps of all the model components.

The USGS model was "constructed" using the modular, three-dimensional, finite-difference, groundwater model MODFLOW, developed by McDonald and Harbaugh (1988). A "constructed" model consists primarily of input files that contain information on the properties of the modeled area. Some properties describe the physical attributes of the area—such as its geometry, boundary conditions, and thickness and hydraulic conductivity of the geologic strata. Other properties describe the "sources" and "sinks" of water to the groundwater flow system—recharge, streams, and pumping wells. Once these files are created, MODFLOW was run to simulate groundwater flow under the conditions described by the input file. Simulation output includes groundwater elevations and streamflows.

7.1.1 Grid

The UDB's groundwater flow system is represented by a grid of cells: 87 north-south trending columns and 127 east-west trending rows. The grid cell size is smaller where the most hydrologic data is available and larger where less data is available (the less populated places with fewer wells). Eight layers are used to represent vertical changes in geology and allow simulation of vertical head gradients and groundwater movement. Each layer is of uniform thickness—100 feet for layers 1 through 5; 200, 300, and 800 feet, respectively, for layers 6, 7, and 8. The complex geology is represented by zones of hydraulic conductivity ranging from less than 1 to more than 1,000 feet/day. In the Thornburgh property vicinity, hydraulic conductivity is higher in layers 3 through 7 than in layers 1 and 2.

7.1.2 Pumping & Stream Nodes

The pumping well data used in the USGS model (Gannett and Lite, 2004) is discussed in detail in Gannet et al. (2001). The model considers only irrigation and public supply wells. Pumpage for irrigation was reported to be about 20.4 cfs (4,812 MGY) in 1994. Total pumpage for public supply was reported to be about 20.8 cfs (4,906 MGY) in 1996. The total pumping from wells in the input file, *des.wel.all*, is 31.2 cfs (7,369 MGY), using annual averaging for the steady-state model to account for the seasonality of the irrigation pumping.

Grid cells that coincide with the location of significant streams were identified as "stream cells," which occur in the top three model layers (1, 2, and 3). Such a cell is identified in layer 2 at locations where the stream is incised to depths below the bottom of layer 1. Similarly, a stream cell is identified in layer 3 at locations where the stream is incised to depth below the bottom of layer 2. Seepage data (Section 6.5) was used to identify the streamflow in each cell. Streamflow at a given cell is head-dependent; in other words, it changes depending on the groundwater level and the streambed conductance. If groundwater level in a cell decreases, the streamflow component originating from the groundwater would also decrease. Conversely, if groundwater level in a cell increases, streamflow in that cell would also increase. Detailed discussion of the movement of groundwater to and from streams in the model is in Gannett and Lite (2004).

7.1.3 Recharge

Recharge to the ground-water system from infiltration of precipitation, canal leakage, and deep percolation of applied irrigation water is simulated as specified flux to the upper-most layer of the model. These recharge values vary from cell to cell. The methods used to estimate recharge from all sources are described in detail in Gannett and others (2001).

7.1.4 Steady State & Transient Simulations

The USGS conducted both steady state and transient simulations. Steady state implies that, except for rates for recharge, discharge, and streamflow, no time variable is incorporated into the input or output files. In other words, wells pump at the same rate the entire time, and the results represent equilibrium conditions. Conversely, transient conditions consider time, so the input data may incorporate wells that are pumping at certain rates for a certain amount of time. Similarly, recharge may occur at one rate during one year, or part of year, and a different rate during a different year, or part of year. The period of the USGS' transient simulation was from 1978 to 1997, using two time periods per year. The results of the transient simulation apply to specific time periods.

7.1.5 Calibration

The steady-state model was calibrated to the water-level contour map prepared using measurements made between 1993 and 1997. During calibration, input parameters are adjusted until the model results are consistent with observed measurements. Hydraulic conductivity was the primary parameter adjusted to achieve calibration (Gannett and Lite, 2004).

7.2 Data Source for New Runs

The UDB groundwater flow model was obtained from the USGS (Gannett, pers. comm., 2007), along with all data input and output. The six proposed Thornburgh wells were located using a map along with the description included in the draft permit to appropriate waters for application G-16385, issued to Thornburgh Utility Group by OWRD. Each well location is described by a given distance in the east-west and north-south directions from a specified section corner.

The pumping rate for each well was based on the withdrawal amount indicated in the water right application. The draft permit is for an annual withdrawal of 2,355 acre-feet (about 767 MGals) and a maximum instantaneous withdrawal of 9.28 cfs or 4,165 gpm[12]. For the steady-state model, a constant pumping rate of 3.25 cfs was used, which is equivalent to the annual withdrawal of 2,355 acre-feet if the well is pumped continuously for 1 year. The rate of 3.25 cfs, referred to in this report as Q-average, was divided evenly between the six wells indicated on the draft permit. The rate of 9.26 cfs is referred to as Q-max.

Pumpage was reported to be about 20.4 cfs (4,812 MGY) in 1994 for irrigation and 20.8 cfs (4,906 MGY) in 1996 for public supply use (Gannett et al., 2001). The steady-state model uses annual averaging to account for the seasonality of the irrigation pumping. The total pumpage from wells in the USGS steady-state model is 31.2 cfs (7,369 MGY).

7.3 Verification of USGS Steady-State Model

We verified the results of the USGS steady-state model by using the input files from the simulation to run MODFLOW with Groundwater Vistas. We then compared output to confirm that Groundwater Vistas yielded the same results as the USGS MODFLOW software. The groundwater level in each cell/layer combination from the USGS output was subtracted from the corresponding groundwater level we generated; the results indicated essentially no difference between our output and the USGS output.

7.4 Steady State versus Transient Conditions

The results of the steady-state and transient simulations are compared in the USGS report (Gannett and Lite, 2004). Most impacts from pumping wells occur on the Deschutes River after about 7 years (transient conditions); about 50 percent of water pumped from the wells comes from storage and about 50 percent comes from the stream. After 10 years, 58 percent is from diminished streamflow, and after 42 years, 90 percent is from diminished streamflow. After about 10 years, the cone of depression will have stabilized even if pumping is greater in the summer and less in the winter. The cone appears stable, with a local-scale contraction and expansion that occurs in response to each pumping cycle. Therefore, steady state is appropriate for evaluating the long-term effects of pumping from the proposed Thornburgh wells on water levels and streamflow.

[12] *The final permit wis issued for 2,129 acre-feet (annual) and 9.97 cfs peak flow.*

7.5 Simulations with Proposed Thornburgh Wells

7.5.1 Method

Two simulations were conducted to evaluate the potential impacts of pumping from the six proposed Thornburgh wells. Scenario 1 simulates pumping from shallow wells in layer 2, and Scenario 2 simulates pumping from deep wells in layer 7. The bottom of layer 2 is about 200 feet below land surface. The bottom of layer 7 is more than 700 feet deep. Simulations were conducted using Q-average and Q-max for each scenario. The six proposed wells were added to the well input file, and Q-average or Q-max was divided evenly between them. Even though Q-max is the permitted maximum instantaneous withdrawal rate (presumably for the high-demand water use season), we used it to evaluate the upper limit of instantaneous impact on Deschutes River flow.

The specifics of how water would be pumped, distributed, applied (for domestic and irrigation purposes), and treated (as wastewater) are currently unknown for the proposed Thornburgh project. It is possible that a portion of the proposed project wastewater could be treated and recharged to the groundwater system, potentially offsetting some of the impact to river, and thereby reducing the Q-average and Q-max to values that reflect consumptive water use[13]. However, until a water management plan is developed, we will assume that the Q-average and Q-max are appropriate for our modeling.

The numerical solver, PCG5, was used for the simulations run during our study to evaluate impacts from the proposed Thornburgh wells. To establish baseline conditions, we used PCG5 with the USGS steady-state model. We then compared these baseline results to the results from our simulations incorporating the proposed Thornburgh wells.

Using ArcMap, the stream cells that lie within the reaches of concern on the Deschutes and Whychus Creek were identified. A table with these cells was imported into the database, and the simulation results for these cells were brought into an Access database. For each stream cell, the baseline condition was subtracted from simulation results to calculate diminished streamflow within these reaches. Finally, we used ArcMap to map diminished streamflow for each stream cell.

[13] *Consumptive uses result in a net loss to the hydrologic system. Water that is "lost" to evapotranspiration is considered consumptive use, for example.*

7.5.2 Results

7.5.2.1 Diminished Streamflow

Table 7-1 summarizes diminished streamflow for Scenario 1 and 2 within several reaches: Bend to RM 149 on the Deschutes and Odin Falls to Whychus on the Deschutes and lower Whychus Creek. Combined diminished streamflow within these reaches is 2.33 cfs, or 72 percent of total pumping, for Scenario 1 (from shallow layers), and 2.08, or 64 percent or total pumping, for Scenario 2 (from deep layers). Total diminished streamflow for the entire stream system (all the stream cells) is 95.1 percent of total pumping for Scenario 1 and 99.7 percent of total pumping for Scenario 2. The difference in evapotranspiration between baseline conditions and Scenarios 1 and 2 accounts for the 4.9% and 0.3% of total pumping that does not manifest in diminished streamflow.

Figures 7-1 and **7-2** show diminished streamflow for stream cells. Values less than 0.01 are omitted. Diminished streamflows of 0.01 to 0.02 cfs are shown in pink, and values of 0.02 to 0.1 cfs are shown in dark red. The majority of diminished streamflow occurs within the reach from Odin Falls to Whychus (Squaw) Creek, which has the most cells with values between 0.01 and 0.02 cfs. While diminished streamflow for each cell seems small and insignificant, it adds up to a significant percentage of the total pumping amount.

Under Scenario 1, pumping from layer 2 will have a greater effect on shallow groundwater levels than it will under Scenario 2, where pumping is from Layer 7. Evapotranspiration is modeled as a head-dependent function. Therefore, when the water level in a cell declines below the "extinction depth" of 5 feet, as the USGS model assumes, no evapotranspiration occurs. As water levels decline under Scenario 1, evapotranspiration is less than what occurs under the USGS assumptions, and more water is "available" for the wells. Pumping from layer 7 does not affect shallow groundwater as much, and therefore does not affect evapotranspiration.

7.5.2.2 Water Level Change

The change in water level, or the drawdown, due to pumping the proposed Thornburgh wells was calculated for each layer under both scenarios. The new water level elevation in each layer was subtracted from the corresponding baseline water level, yielding results that are consistent with what is expected based on hydraulic conductivity in the vicinity of the Thornburgh wells.

Drawdown contours are shown on **Figures 7-3** through **7-8**. In general, drawdown is similar for the two scenarios, except for layer 2. Contours are, in general, broad, and maximum drawdown is less than 1 foot. Drawdown in the pumping layer is significantly larger for Scenario 1 (layer 2, **Figure 7-5**) than for Scenario 2 (layer 7, **Figure 7-8**). Maximum drawdown is 8 feet in the pumping layer in Scenario 1 (**Figure 7-5**) and 0.6 feet in Scenario 2 (**Figure7-8**). Maximum drawdown is 0.5 foot in layer 1. Contours are not shown for each scenario/layer combination because they are similar, but are shown for layer 1 because it is the most shallow, and layers 2 and 7 because they are the layers from which modeled pumping occurs.

Maximum drawdown is larger in layer 2 than layer 7 because hydraulic conductivity is lower in layer 2 in the Thornburgh vicinity. The thicknesses of layers 2 and layer 7 are 100 and 300 feet, respectively. Transmissivity, the ability of an aquifer to transmit water to a well is the product of aquifer thickness and hydraulic conductivity. Therefore, transmissivity is significantly larger for layer 7. While maximum drawdown is only 0.4 feet in layer 2 for Scenario 2, the convoluted nature of the contours illustrates the effect of lateral change in hydraulic conductivity. The large drawdown in layer 2 accounts for the larger impact to streamflow in the selected reaches for Scenario 1 as compared to Scenario 2.

7.5.3 Effects of Recent Data on Model Results

7.5.3.1 Hydrologic Data

Data presented in Section 6.2 indicates that, locally, groundwater levels have declined since the USGS investigation. Therefore, groundwater discharge to streams will have decreased, resulting in diminished streamflow relative to baseline conditions. Similarly, if climate change results in less precipitation and duration of snow pack, then the groundwater system would receive less recharge—also resulting in diminished streamflow relative to baseline conditions. Although the absolute value of the impact to the stream from the proposed Thornburgh pumping cannot exceed the Q-max (3.25 cfs), the impact as a percentage of streamflow will increase as streamflow diminishes.

7.5.3.2 Geologic Data

Hydrothermal alteration associated with Cline Buttes rhyolite dome complex has likely reduced the hydraulic conductivity of the rhyolite and adjacent Deschutes Formation (Section 5.3.2). The reduced hydraulic conductivity likely occurs at depth throughout the entire model-layer sequence. The conductivity of the altered rhyolite and Deschutes Formation is likely to be significantly lower than that assigned in the model.

The USGS model was calibrated by adjusting hydraulic conductivity; as such, the conductivities assigned to the Cline Buttes area may yield the observed water level measurements. However, if the low conductivity Cline Buttes rhyolite complex occurs in the vicinity of the Thornburgh resort, water levels would decline more locally in response to pumping—and the contours might resemble those for layer 2, Scenario 1 (pumping from layer 2, **Figure 7-5**) instead of the broad contours shown in **Figures 7-3**, **7-4**, **7-7**, and **7-8**.

7.5.3.3 Current & Future Water Use

Private water use in the central part of the UDB was 4,093 MGY (17.35 cfs) in 2003 and 2,658 MGY (11.27 cfs) in 2006. Water use for public supply has increased by more than 300 percent since 1997 (**Table 6-2,** Section 6.4). Water right permits since 1998 have granted 44 cfs (Section 8). Considering these trends, current withdrawals are significantly higher than the USGS model assumed. Therefore, the impact to streamflow from pumping the Thornburgh wells at 3.25 cfs becomes a significantly larger percentage of streamflow if the streamflow rate decreases.

In addition, groundwater levels will likely decline as pumping from public and private wells increases. Water rights applications since 1998 (117 cfs; 27,700 MGY) suggest that future use will be even greater. Pumping of this magnitude can lower groundwater levels significantly, affecting streamflow and stream temperature.

The cumulative effect of pumping from both the Thornburgh and other pumping wells will exceed the water level decline predicted by the model (Gannett and Lite, 2004).

8.0 Water Rights Activity

This section presents an analysis of water rights activity in the study area. Water rights provide important information about changes in current and future water demands and usage. For this analysis, we examined trends in both recently granted permits and recent applications.

8.1 Data Sources

Data was compiled from the OWRD website, which contains a database of all water rights applications and permits[14]. We downloaded all applications and permits in the UDB with a priority of later than 1/1/1998. Information included point of diversions (POD), point of use, and stakeholder data. Point of diversion and stakeholder data was downloaded to two separate tables. Township, range, and section information is included for each water right and application. Data in shape file format was also downloaded[15], along with POD and point-of-use data mapped by OWRD[16].

Each record in the POD table corresponds to a unique water right, point of diversion, and water use combination. Therefore, a single water right can have many records if it covers several wells (points of diversion) and if each well has more than one use. For example, the water right application for the proposed Thornburgh development has six records in the water rights database—one for each proposed well. Each well has only one use, quasi-municipal. If there were two types of use for each well (irrigation and municipal), there would be 12 records in the database for that water right application. The terms of the water right permit or application are given by the Q-average and the Q-max. If a well pumped the Q-max rate 24 hours per day, everyday for the entire year, the volume withdrawn would be significantly larger than the Q-average. Once the Q-average has been met, no further withdrawals are permitted. Note that the Q-average is not shown in the database. For this reason, water rights analysis was conducted on the Q-max information.

For the Thornburgh development, the Q-max for the entire right is 9.28 cfs. The database shows this divided between six wells at 1.546 cfs each[17].

[14] *http://apps2.wrd.state.or.us/apps/wr/wrinfo/Default.aspx*

[15] *http://www1.wrd.state.or.us/files/water_right_data*

[16] *http://www.oregon.gov/OWRD/MAPS/index.shtml#Water_Right_Data_GIS_Themes*

[17] *The final order for Thornburgh now has a 9.97 cfs max.*

8.2 Method

The OWRD water rights data were brought into an Access database. Using ArcMap, the township, range, and section information was summarized for the area included within the USGS model area, which is a portion of the larger Deschutes basin. Water rights permits and applications within the model area were extracted. We summarized this data separately and further categorized it by surface water or groundwater. We then calculated the total water use attributed to each right.

Appendix E contains a complete list of water right identification numbers, priority dates, Q-max rates, and the stakeholder information; **Table E-1** lists applications and **Table E-2** lists permits. The number of water rights per year and the annual sum of the individual Q-max rates are summarized for groundwater permits and applications, and for surface water permits and applications in **Tables 8-1**, **8-2**, **8-3**, and **8-4**, respectively.

8.3 Results & Discussion

The moratorium on granting water rights from 1998 to 2002 (Section 3.2) is somewhat apparent in the number of water right permits and water use rate granted each year (**Table 8-1**) and in the relatively small number of water right applications (Table 8-2) during this time. The passage of HB3494 in 2005 (Section 3.2) is very apparent in the large number of water right applications and water use requests (**Table 8-2**) from 2005 to 2007.

Based on water rights granted since 1998 (**Table 8-1**), Q-max withdrawals have increased by as much as 44.14 cfs (10,414 MGY) since the USGS period of record (1993–1997). The USGS steady-state model assumes that about 31 cfs is pumped from wells. If new water rights indicate additional pumping since then, a more realistic value for current conditions is about 75 cfs—more than twice the rate considered by the model.

Table 8-2 indicates that the sum of the Q-max withdrawals was about 5.1 cfs (1,203 MGY) for all water rights applications for the 5-year period from 2000 to 2004. In contrast, the corresponding sum was 117.3 cfs (27,200 MGY) for the 3-year period from 2005 through November 2007. This difference indicates that groundwater pumping will increase dramatically if all these water right permits are granted for each application.

New permits and applications for surface water rights permits are few and for small quantities. One permit (for the U.S. Bureau of Reclamation) is for 2.64 cfs. It seems to be associated with 36 other surface water permits that have priority dates of 1914 and 1917.

9.0 Deepened Wells

In general, water wells are deepened when they no longer provide adequate supplies. If the demand has not changed since the well was installed, a decline in production capacity will result in inadequate supplies. Although such declines may be due to lower well efficiencies, they are most commonly caused by declining water levels. It is reasonable to assume that wells are deepened when the pumping water level reaches the pump intake and yields decrease. As water levels decline, the well intercepts less of the aquifer, and therefore produces less water. As part of this investigation, we examined wells that were deepened over a specific period, within a specific area, around the Thornburgh site, to learn more about possible groundwater level declines.

9.1 Data Source & Method

OWRD maintains an online database of water well logs filed by drillers[18]. The database identifies wells that have been deepened. We downloaded this database for our analysis.

The database includes information about the type of construction conducted for each well and identifies wells that have been deepened. This database was queried based on township, range, and section. The 198-square-mile search area is shown on the **Figure 9-1**.

9.2 Discussion

Since 1980, 210 (of about 3,400) wells have been deepened in the study area[19]. **Table 9-1** summarizes the number of deepened well logs for each 5-year interval since 1980. Well deepening has accelerated since 1980, and 82 wells have been deepened since 2000. This trend is likely to continue in pace with increased groundwater pumping in the area. The increasing rate of well deepening indicates that groundwater levels are declining, likely because of increased pumping by major groundwater users, such as Eagle Crest Resort and the City of Redmond, and, to some degree, by reduced annual precipitation.

[18] *http:// www.wrd.state.or.us*

[19] *The actual number of wells in the study area is somewhat lower because multiple logs have been filed for some.*

The Cline Buttes and Thornburgh resorts are located near the center of Township 15 South, Range 12 East. Fifteen wells have been deepened within this area (**Appendix B**). Of these, 13 wells were deepened between 2001 and 2007. These wells are located near the Eagle Crest Resort (**Figure 5-2**). Well logs for four of the deepened wells, 56980, 56063, 56877 and 55438, could be matched up with the original well logs to determine the amount of decline in static water level over time. The declines in water levels for these wells are, respectively, 42 feet between 1995 and 2005, 10 feet between 1982 and 2004, 21 feet between 1976 and 2005, and 3 feet 1985 and 2003. It is likely that the pumping of the Eagle Crest Resort wells has caused a decline in the water table.

10.0 Fish Habitat in the UDB

10.1 Data Sources

We examined critical fish habitat using data available online from the U.S Fish and Wildlife Service (USFW) in shape file format[20]. The data included locations (streams and lakes) of critical bull trout habitat. We also downloaded data identifying the endpoint of the extent of critical bull trout habitat[21].

10.2 Discussion

10.2.1 Bull Trout Critical Habitat

Bull trout is listed as a threatened species under the *Endangered Species Act* (ESA). In October 2004, USFW designated critical habitat for bull trout in the Deschutes River basin (USFW, 2005). Bull trout have more specific habitat requirements than other salmonids; very cold water is the first criteria listed. Bull trout can occupy streams with temperatures ranging from 0° to 22°C, but they are found most frequently in temperatures ranging from 2° to 15°C. There are three listed areas of critical bull trout habitat on the Deschutes River between Big Falls (RM 132) and the mouth of Whychus Creek (RM 123; **Figure 10-1**). Based on our modeling, this reach would be impacted by a reduction in cold groundwater discharges to the Deschutes River due to the pumping of the Thornburgh resort wells. The springs discharging into the river in this reach provide the sole source of cold water for the listed habitat. Any reduction in the flow from these springs will lead to temperature increases in the river. The TIR (**Figure 6-26**) shows that the river temperature in the area of the critical habitat is 12° to 14°C, while just upstream the temperature is 24° to 26°C. A botanical and springs survey of the middle Deschutes River conducted in 2005 for the BLM recorded an average spring water temperature in the critical habitat area of about 10.6°C (WPN, 2006).

[20] *http://criticalhabitat.fws.gov*

[21] *http://www.fws.gov/pacific/bulltrout; the publication date for this data is September 26, 2005.*

10.2.2 Native Redband Trout

ODFW's *Upper Deschutes River Basin Fish Management Plan* identifies a core redband trout population located mostly within two reaches that would be impacted by the pumping of the Thornburgh destination resort wells (Fies et al., 1996; **Figure 10-1**). These reaches are the Odin Falls to Whychus Creek reach on the Deschutes River and the Alder Springs to Deschutes River reach on Whychus Creek. The native redband trout is an Oregon-listed sensitive species. The cold water springs that discharge to the Deschutes River and the lower end of Whychus Creek are essential to maintaining the excellent habitat for the native redband trout in this core population area.

Our modeling shows that pumping the Thornburgh wells will reduce cold groundwater discharges to the Deschutes River from Bend to just south of Cline Buttes. In this reach, native redband trout production is very limited because of low summer flows and high water temperatures (Fies et al., 1996). Even small reductions of cold groundwater inflows will likely have a negative impact on this stressed redband population.

10.2.3 Steelhead & Salmon Reintroduction

A major effort is underway to reintroduce summer steelhead and Chinook salmon to the UDB. This effort focuses on establishing self-sustaining populations in Whychus Creek, where Chinook historically spawned (Fies et al., 1996). The cold water springs that discharge to this creek from Alder Springs down to the mouth of the creek are very important to the success of the reintroduction program (Wise, 2008). Modeling indicates that this reach will see reduced cold groundwater discharges as a result of pumping the Thornburgh wells. The TIR data, plotted on **Figure 6-26**, shows that Whychus Creek water temperature from Alder Springs to its mouth is 12° to 14°C, while just upstream of Alder Springs the temperature is 24° to 26°C.

11.0 Mitigation

11.1 Current Alternatives

This section briefly describes the mitigation program currently used by OWRD to minimize diminishing streamflows in the UDB and to enhance streamflow on the middle Deschutes River. The program is authorized under *Oregon Revised Statute 537.746* and implemented through *Oregon Administrative Rules Chapter 690, Divisions 505 and 521.*

The mitigation program began in 2002. Mitigation, which is required for all new groundwater permits in the UDB, may be accomplished via a mitigation project or mitigation credits, also referred to as "mitigation water." Mitigation water can be acquired by various methods:

- Instream leases
- Time-limited instream transfers
- Permanent instream transfers
- Allocation of conserved water
- Aquifer recharge
- Releases of stored water

For example, an instream transfer occurs when a water diversion at a specific point on the river is terminated to allow a diversion or impact to the stream at a different location. For each new groundwater permit, OWRD determines the zone of impact. Mitigation credits associated with that zone may then be used for mitigation. The zones of impact are shown on **Figure 11-1**.

The ODFW, Oregon State Parks and Recreation Department (OSPRD), ODEQ, and BLM all have an obligation to evaluate the appropriateness and effectiveness of mitigation for new groundwater permits. These agencies are charged with protecting resources that will be impacted by future groundwater withdrawals that are not properly mitigated. This section addresses elements of the mitigation programs for which we have identified concerns.

11.2 Concerns

11.2.1 Zone of Impact

The OWRD determined for Thornburgh that the zone of impact is the general river zone **(Figure 11-1)**—that is, the entire Deschutes River basin above the Madras gauge. This means that it could be acceptable to use mitigation water from a stream diversion or impact that currently occurs downstream of the stream reaches shown to be impacted from proposed Thornburgh pumping. Under this condition, the impact would not be mitigated; instead, more water would simply flow downgradient of the point of impact from the mitigation water. Temperature at the reaches impacted by Thornburgh pumping would increase due to pumping. This impact would not be mitigated under the conditions described above.

Our simulation of pumping from the Thornburgh wells indicates that decreased groundwater discharges, and therefore decreased streamflow, to the middle Deschutes River and lower Whychus Creek. These impacts must be mitigated using credits or projects that target the middle Deschutes River Zone and the Whychus Creek zone—specifically, the reaches indicated by our modeling efforts.

11.2.2 Canal Lining or Piping / "Conserved" Water

Lining existing canals or conveying water via pipes instead of canals would eliminate losses due to leakage. The mitigation rule allows this so-called "conserved" water to be used to mitigate new groundwater pumping. However, water leaked from canals eventually discharges to streams downgradient and comprises an important part of the local hydrogeologic system. This mitigation scheme would increase streamflow at the canal diversion; however, downstream groundwater discharge into the stream is diminished. In addition, groundwater discharge to streams would be further diminished by the newly permitted groundwater pumping.

Groundwater mitigation based on this so-called "conserved" water would have a long-term, cumulative impact on water quality—specifically temperature—because it reduces cold groundwater discharge into streams.

11.3 OWRD Evaluation

OWRD evaluated the first 5 years of the mitigation program (OWRD, 2008). In general, the report concludes that the mitigation program is successful based primarily on two factors: increased streamflow (which is documented in the Deschutes River at Bend), and the availability of plenty of mitigation water "in the bank."

The OWRD report shows a graph of streamflow at Bend from 4/1/2007 through 9/30/2007 and compares it to monthly average for the period of record at this stream gauge. The graph shows that streamflow was about 100 cfs during low-flow conditions in 2007 and that monthly mean streamflow for the period of record during these months was less, ranging from about 50 to 60 cfs. The graph illustrates that, compared to earlier conditions, the mitigation program has increased streamflow at Bend. However, it is important to note that this graph only monitors the effectiveness of mitigation credits that affect reaches upstream from Bend. The OWRD report indicates that no other gauges are available for evaluating the effectiveness of mitigation in other parts of the basin. Furthermore, there is no data addressing the effect of mitigation on stream temperature—a very important parameter for maintaining a healthy stream.

The Deschutes Water Alliance comprises representatives from major stakeholders in the UDB, including cities, irrigation districts, the Deschutes River Conservancy, and the Confederated Tribes of Warm Springs. The working mission for this group with diverse needs includes the objective of moving streamflow

> *"toward a more natural hydrograph while securing and maintaining improved instream flows and water quality to support fish and wildlife."*

A more natural hydrograph is one that represents conditions before so much water was diverted from streams in the UDB. The Deschutes River has a Wild and Scenic designation; as such, returning to a more natural condition is appropriate. This mission statement reminds us that the success of the mitigation program should be measured by how well streamflow is returning to the natural condition to enhance its wild nature—not just by documenting that flows exceed the lowest, or most impacted, condition ever recorded. The OWRD evaluation fails to consider this mission.

If the Thornburgh Resort is developed and mitigation occurs in the general zone, pumping from the six new wells would likely still impact the river in the vicinity indicated by the model (Section 7)—even if mitigation is allowed anywhere above Madras gauge. Yet, based on the OWRD's method of evaluation, the mitigation program would still be considered successful as long as flows at Bend are higher than historic flows. As such, the method used to evaluate the success of the mitigation program needs to be improved.

12.0 Analysis of Projected Impacts

In Section 6 we analyzed data collected over the last 10 years to identify trends that will affect future water and ecological resources in the UDB. In section 7 we conducted modeling to evaluate the effect of pumping Thornburgh wells on the hydrogeologic system. In Sections 8, 9, and 10 we analyzed water rights activity since 1998, deepened wells in the Thornburgh vicinity, and fish habitat, respectively. This section summarizes the results of these analyses with respect to impact to water resources and the current mitigation program (Section 11) and offers a roadmap for evaluating the impacts of future development.

12.1 Impacts Related to Thornburgh Case

12.1.1 Modeling Results

Our model simulations show that pumping from the new Thornburgh wells will reduce streamflows primarily in two segments of the middle Deschutes River and lower Whychus Creek (**Table 7-1**, **Figures 7-1** and **7-2**). The two reaches on the Deschutes River are from Bend to just south of Cline Buttes (RM 149) and from Odin Falls to the mouth of Whychus Creek. On Whychus Creek, streamflows are reduced from approximately Alder Springs downstream to the Deschutes River.

These streamflow reductions are related to groundwater level declines. Because a significant portion of streamflow originates from groundwater seepage—especially during the low-flow season—these declines mean less groundwater is available to feed the stream. Reaches of the Deschutes River near the proposed Thornburgh development are especially vulnerable to water level declines because baseflows are relatively low. Water level decline could also affect Whychus Creek, which has base flows of about 7 to 15 cfs, and Tumalo Creek, which has baseflows of 10–20 cfs.

All of these reaches are important to fish resources near the proposed development.

12.1.2 Related Impacts

The predicted groundwater level declines—and the resulting reductions in streamflow—also have profound impacts on stream temperatures, which in turn can impair fish habitat. The mildly gaining reaches are especially vulnerable to water level declines, which can lead to higher water temperatures because less cool groundwater is available to enter the stream.

Groundwater level declines also impact existing wells and water rights. As water levels decline, a well's production may also decline. Many owners in the UDB have already resorted to deepening their wells to obtain the supplies they need.

12.2 Climate Change

If future precipitation is less than historic precipitation, this will eventually manifest in reduced streamflow. If impact to streamflow from groundwater pumping is expressed as a percent of streamflow, then relative impact from pumping would be greater under conditions of reduced precipitation and reduced streamflow.

12.3 Habitat Resources

Pumping from the six proposed Thornburgh wells will cause water level declines and associated reductions in cold spring discharges. It is reasonable to assume that if mitigation for the Thornburgh wells does not occur at the specific reaches affected by pumping, cold water discharge into the stream will be less at those reaches, causing water temperatures to increase on both the Deschutes River and Whychus Creek. Increased stream temperature negatively impacts not only critical habitat for bull trout, a federally listed species, but also a core redband trout population. In addition, this warming trend will impede the success of the reintroduction of Chinook salmon and summer steelhead.

12.4 Considerations for Future Developments

In a region that is growing as rapidly as the UDB, it is imperative to consider impacts in the context of trends in water usage. Although the impacts on streamflow due to pumping the Thornburgh wells alone will never exceed 3.25 cfs (the Q-average), the effect of declining groundwater levels is cumulative. If streamflows decrease, impacts to the Deschutes River from the proposed Thornburgh development would become more significant because they would represent a larger percentage of streamflow.

Furthermore, groundwater development will undoubtedly continue in the UDB, and water level declines will be additive. It is reasonable to assume that pumping the six wells at the Thornburgh destination resort will contribute to the rate of groundwater level decline, perhaps requiring other wells in the area to be deepened. Similarly, while reduction in stream temperature from reduced cool groundwater inflow due to Thornburgh pumping may be relatively small, the cumulative effect from other groundwater developments in the vicinity will be significant.

Section 13, "Recommendations," lists specific actions that planners can take to ensure the long-term health of ecosystems along the Deschutes River.

13.0 Recommendations

Agencies and planners should...

- ...consider the cumulative impact of individual proposed groundwater developments rather than considering each one individually.
- ...require the use of the best available scientific method to evaluate the impacts of groundwater development on water resources.
- ... acknowledge the effects of lining and piping canals on groundwater levels and related groundwater discharges to streams. The "conserved" water may enhance flows at the diversion, but any benefits are subtracted downstream because groundwater discharges to streams are diminished.
- ...acknowledge that when pumping is not mitigated at the place of impact, cold groundwater discharges to streams are reduced, resulting in higher water temperatures. A greater emphasis on evaluating and monitoring water quality is needed.
- ...target mitigation for Thornburgh pumping to the middle Deschutes River and Whychus Creek zones, which will be impacted the most.
- ...monitor stream temperature and use the data to measure the effectiveness of mitigation.
- ...address the Endangered Species Act and other laws protecting fish and fish habitat when considering groundwater withdrawals.
- ...use the natural hydrograph for Deschutes River as a means by which to evaluate the success of water resource management in the UDB, rather than a comparison to the historic low flow.

The critical habitat listing prohibits federal actions that would adversely modify critical habitat ODFW, ODEQ, OSPRD, and the BLM should develop programs specifically to monitor and evaluate the effectiveness of mitigation for new groundwater development.

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Ref: Thornburgh Resort - rebuttal and comment in response to applicants written and oral testimony submitted to Anne Corcoran Briggs, Deschutes County Hearings Officer, on July 15, 2008.

Dear Mr. Munson:

The following are my responses to written and oral testimony given to Anne Corcoran Briggs, the hearings officer for the Thornburgh Master Plan proceedings, presented by the applicant's representatives on July 15, 2008.

Thornburgh Memo, Exhibit G

The Thornburgh memo is incorrect when it states that we "attempts(ed) to run the USGS model". We did run the model using an installation of the model that was verified to be operating correctly on our computer. The only change to the USGS groundwater flow model was to add the Thornburgh wells and their pumping rate. We also used a newer numerical solver to improve computing efficiency.

The Thornburgh memo also incorrectly characterizes our use of the USGS groundwater flow model as inadequate or inappropriate to "determine site specific impacts". The model is simply used to evaluate the impact of the pumping of the Thornburgh wells. The modeling results show both near and distant effects on groundwater levels and discharges to streams. The model was calibrated by the USGS and model simulation runs done by the USGS closely fit observed data in the area most significantly impacted by the pumping of the Thornburgh wells. Our use of the model is appropriate. The USGS demonstrated the usefulness of the model by using it to evaluate the impact of a hypothetical well near Redmond on groundwater discharge to the Deschutes River (Gannett and Lite, 2004).

The Thornburgh memo also characterizes our results as being in conflict with OWRD's determination of the zone of impact to be the general zone. There is no conflict here at all. It is simply that our approach used the peer reviewed and calibrated flow model to produce a much more detailed evaluation of where the impact of Thornburgh's groundwater pumping will occur. OWRD's evaluation (OWRD, 2005) merely states that the Thornburgh wells will withdraw water from the Deschutes Formation and that groundwater discharges to the Deschutes River 5.8 to 8 miles north of the proposed resort. Thornburgh misused this simple description to justify ignoring impacts to Whychus Creek and focus mitigation only on the Deschutes River.

Kyle Gorman, OWRD's South Central Region Manager, in his oral testimony on July 15, 2008 stated:

> "Our department, if we ran the model, we wouldn't find that the impacts would be in the Sandy River. We'd find that they'd (impact) be in the exact same place that Yinger found."

If OWRD had run the model to evaluate the impact of the pumping of the Thornburgh wells they would have found that there are impacts to Whychus Creek, just as we have.

By repeated reference to OWRD's use of "site specific" information Thornburgh further attempts to show a conflict between our evaluation and OWRD's evaluation where there is none. The site specific information used by both Mark Yinger Associates and OWRD is the same. We both used the same well locations and pumping rates provided by the applicant in their water right application.

On page nine the Thornburgh memo admits that using the USGS model can yield more site-specific information concerning impacts. I agree. The memo then suggests that because our data inputs and results are not peer reviewed our results cannot be relied on. This is unfounded. Again, the data input for our USGS model runs was the well locations and pumping rate specified by the applicant in its water right application. The USGS model is peer reviewed therefore; there is no point in a peer review of the modeling results. Has the work of the applicant's consultants been peer reviewed? It has not been. Thornburgh's insistence on peer review of our work by extension must also apply to the work of the applicant's consultants.

I disagree with the consumptive water volume of 1,356 acre feet per year for several reasons:

1. The intent of the mitigation is to protect fish habitat from impact by this particular project. The USGS groundwater flow model is the best method to define where that impact will occur. Mitigation must be targeted to these areas and address both water quantity and quality; the cold groundwater crucial to fish in the impacted reaches. It is not sufficient protection of the habitat in the impacted stream reaches to simply return water back into the surface water system anywhere. It is unlikely that the potentially unconsumed water will actually end up discharging to the streams where it would have if it had not been pumped in the first place. The potentially unconsumed water cannot be presumed to mitigate the impact resulting from the withdrawal of groundwater by this particular project on streamflow and fish habitat. This is one reason we used the full annual volume specified by the applicant in their water right application for our groundwater modeling.

2. The applicant's assumptions concerning consumptive use are not supported. The claim that standard irrigation is 60% consumed and 40% recharges the aquifer would only be reasonable if flood irrigation were used, which will not be the case. In the USGS groundwater hydrology report for the upper Deschutes Basin, modern sprinkler irrigation is assumed to result in no recharge (Gannett and others, 2001). This is based on a review

of irrigation practices in the basin. The following statement is made in the USGS hydrology report:

> "In areas of sprinkler irrigation with efficiencies of 94 percent, only 6 percent of applied water is lost (mostly to evaporation and wind drift), and no water is assumed to be lost to deep percolation [recharge]."

The applicant's use of the consumptive/non-consumptive ratio of 40%/60% for standard irrigation is based on an OWRD study that compared the water meter totals to outfalls of sewage treatment plants. The difference between water metered to customers and sewage treatment plant outfall flow is assumed to be the amount of water consumed. It is inappropriate to apply this reasoning to modern irrigation practices.

Early in our study we did an informal poll of golf courses managers in the area. The universal response of greenskeepers and agronomist, was that 100% percent of the water applied to the golf course is consumed by the turf and direct evaporation, leaving none to recharge groundwater.

The claim that only 40% of the 971 acre feet for quasi-municipal use is consumed is not supportable. The portion of this water that is not directly consumed will end up in the resort's sewage system which is designed to evaporate the waste water to prevent it from potentially impacting groundwater quality. This is a requirement of the resorts waste water treatment permit issued by the DEQ. In Newton Consultant's July 15, 2008, response letter the following statement is made:

> "Much of the water used for domestic, municipal and quasi-municipal purposes returns to ground water via septic systems and sewage treatment systems, and through seepage from landscape irrigation."

This is contrary to the conditions of the DEQ issued permit for waste water treatment and the design of the sewage treatment system.

If we had assumed, for the purpose of our groundwater modeling, that 90% of the pumped water was consumed and 10% recharged groundwater it would not have had a substantial impact on our modeling results. The use of a mitigation obligation of 1,356 acre feet is not realistic and will result in unmitigated impacts to streams and fish habitat. The mitigation obligation should be at least 1,916 acre feet.

On page 10 the Thornburgh memo attempts to related their determination of consumptive use with the intended use of the USGS model. The determination of consumptive use has nothing to do with the USGS model. In fact, their determination of consumptive use ignores pertinent findings in the USGS Deschutes Basin hydrology study (Gannet and others, 2001), such as the rate of recharge attributed to different irrigation practices.

On page 11 the Thornburgh memo states to the effect that using the Big Falls Ranch water will mitigate impacts to Whychus Creek. The use of Big Falls Ranch water will not mitigate impacts to Whychus Creek. Whychus Creek is not down stream of Deep Canyon Creek. The memo goes on to imply that ODFW agrees that Big Falls Ranch water will mitigate impacts to

Whychus Creek. In their June 13, 2008, letter ODFW did not say that Big Falls Ranch water will mitigate impact to Whychus Creek (ODFW letter attached).

The Thornburgh memo is correct, that we did not quantify temperature impacts to streams. However, the applicant's consultants have quantitatively confirmed that there would be stream temperature increases. The statement that Tetra Tech's analysis indicates that temperature impact to Whychus Creek is "statistically insignificant" is not correct. No statistical analysis was done by Tetra-Tech.

Tetra Tech Memo of July 2, 2008

The stated purpose of the Tetra Tech memo of July 2, 2008 is to review Thornburgh's mitigation plan assuming that our conclusions that there will be impacts to the Deschutes River and Whychus Creek are correct. They then go on to describe at length mitigation flows to address impacts to the Deschutes River. These impacts would result in a stream temperature increase in a reach of the Deschutes River that includes listed bull trout habitat. However, they ignore Whychus Creek because the Thornburgh mitigation plan provides no mitigation for Whychus Creek. The abandonment of three domestic wells on the Thornburgh property and providing funds for thermal modeling of Whychus Creek does not mitigate the impacts that this particular project will have on Whychus Creek.

Tetra Tech Memo of July 8, 2008

On page one of Tetra Tech's memo of July 8, 2008, under "Similarities of the Two Methodologies" the statement that both we and Tetra-Tech based analysis on the *Simulation of Regional Ground-Water Flow in the Upper Deschutes basin, Oregon* prepared by the USGS (Gannett and Lite, 2004) is misleading. Tetra Tech has not run the groundwater flow model, which is presented in USGS report, to evaluate the impacts of the pumping Thornburgh wells. Our analysis used the USGS model and is much more thorough and detailed.

On page 4 in the third bulleted item the statement is made that their calculations are conservative because if local lithology were considered the "direction proportional connection between groundwater pumping and stream flow" would become less. That is not supported by any significant discussion of geology either in this memo or early work by Tetra Tech. The fact is that they have not used the best analytical tool available which is the USGS groundwater flow model, which accounts for complex heterogeneous geology through defining 171 zones of hydraulic conductivity and model calibration.

At the beginning of the memo Tetra Tech says that they based their analysis on the USGS modeling report (Gannet and Lite, 2004) and then on page 5 in the first bulleted item under "Comments Regarding the Yinger and NWLW, Inc. Methodology" they attempt to dismiss the use of the USGS model. This is a contradiction. They present the same argument they presented in their May 2008 evaluation (Tetra Tech, May 2008). Their argument is simply an excuse for not using the groundwater flow model themselves.

The use of the USGS groundwater flow model to evaluate the impacts of Thornburgh pumping is appropriate and the best method for the following reasons:

1. The USGS groundwater flow model for the upper Deschutes River Basin is a calibrated model, peer reviewed and published. Our input to the model consisted of only well locations and pumping rate specified in the applicant's water right application.

2. The USGS groundwater flow model utilizes a large body of observed data. This data includes: geologic mapping, boring logs, well logs, geophysical logs, groundwater levels from observation wells, private wells and public wells, well and aquifer tests, precipitation, streamflow, groundwater seepage, evapotranspiration and pumpage. The numerical model is the best method to synthesize all of this data and a conceptual model in order to predict the behavior of a complex natural system in response to new stress such as the pumping of wells.

3. The USGS groundwater flow model does account for complex heterogeneous geology through defining many zones of hydraulic conductivity within each model layer and through the calibration of the model. The eight layers of the model are divided into a total of 171 zones based on hydraulic conductivity. To demonstrate the use of the model the USGS used it to simulate the impact on streamflow for a hypothetical well in the Redmond area (Gannett and Lite, 2004).

4. In the area of interest, the groundwater discharge to streams simulated by the model closely matches measured or estimated discharge values, which are based on data from seepage runs, gauging stations and streamflow measurements (Gannett and Lite, 2004). The fit between simulated and measured or estimated discharge of groundwater is close for the Deschutes River between Lower Bridge and the gauge near Culver.

The first bulleted item on page 6, is not correct in saying that we did not use "site-specific pumping scenarios for the proposed water supply wells because it is not applicable to apply the USGS model .... to localized impacts from pumping." First, we used the used well locations and pumping rates specified by the applicant in their water right application. This is the same site specific data used by OWRD in their analysis contained in the Public Interest Review for Ground Water Applications (OWRD, 2005). Second, it is applicable to use the USGS model to evaluate the impact of the proposed pumping. The modeling results show both near and distant impacts to groundwater level and discharges to streams. Again, the authors of the USGS groundwater flow model chose to demonstrate its usefulness by modeling the impacts on streamflow for a hypothetical well in the Redmond area.

The second bulleted item on page 6 is correct in that we did not quantify stream temperature changes. We did predict temperature changes and Tetra Tech's calculations appear to confirm our prediction. I find it hard to understand how they can claim here that an increase in water temperature "*may be*, valid" when in fact they show that there will be an increase in temperature by their own calculations.

I addressed the issue raised in the third and fourth bulleted items on page 6 regarding consumptive use above. Our use of the actual annual pumping rate is justified. For mitigation to be effective it must be targeted at the areas impacted by the pumping. Returning water anywhere in the hydrologic system will not mitigate the impacts of this particular groundwater withdrawal.

The last bulleted item, page 6, cites some of the good reasons to use the USGS calibrated groundwater flow model to evaluate the impact of the pumping of the proposed Thornburgh wells. We use site specific data based on the information contained in the applicant's water right application. The results of the modeling show both local and distant impacts on groundwater level and groundwater discharges to streams.

The following addresses only some of the issues I have with the table attached to Tetra Tech's memo:

1. The first item in the summary table deals with our use of the USGS groundwater flow model. It is inappropriate to complain that it is difficult to evaluate our modeling results. All the information that is needed to exactly duplicate our modeling results are contained in our report (Yinger and Strauss, 2008). Tetra Tech can acquire the groundwater model from the USGS and run it themselves.

To raise the issue of a natural hydrograph is simply a pointless obfuscation. The flow conditions on the middle Deschutes River and Whychus Creek have not been remotely near a natural hydrograph for many decades.

2. On page 38 of our report we do have a typo error. The instantaneous pumping rate given as 9.26 cfs should have been 9.28 cfs. Everywhere else in the report the value of 9.28 cfs is given. This typo has no impact on our modeling results.

3. Tetra Tech questions our use of the figure of 31.2 cfs. The USGS report does not contain the figure of 31.2 cfs for total pumpage used in the USGS steady state model (Gannett and Lite, 2004). However, the figure of 31 cfs is given in Table 5 of the USGS report. The values in this table are apparently rounded to whole numbers. The exact figure of 31.2 cfs comes from the well input file of the steady state groundwater flow model. The rest of Tetra Tech's discussion related to 31.2 cfs is confused and pointless. Again, if they disagree with our modeling results they can acquire the model from the USGS and run it themselves.

Tetra Tech Memo of July 14, 2008

Tetra Tech's July 14, 2008 memo addresses the impacts to lower Whychus Creek.

On page 2, the first bulleted item is not correct when it states that the flow from Alder Springs is 100 cfs. The source of their data cannot be checked as it is not identified adequately. To the point, the flow from Alder Springs is much less. In Table 1 of *Deschutes River, Whychus Creek, and Tumalo Creek Temperature Modeling* prepared by Watershed Sciences (2008) for the DEQ the value given for the flow from Alder Springs is 8.7 cfs on July 26, 2000. The 100 cfs volume is approximately the total flow gain on Whychus Creek between Alder Springs and the mouth of the creek.

If the reduction of groundwater discharge, at 0.15 cfs, as indicated by our use of the USGS groundwater flow model occurs at Alder Springs there will be a significant increase in the temperature of Whychus Creek. Alder Springs is located at the top of the spring system and significantly lowers the temperature of lower Whychus Creek. Using the 0.15 cfs reduction in cold groundwater discharge and Tetra Tech's thermal mass balance approach the increase in temperature of Whychus Creek at Alder Springs would be 0.07° C. This is based on a pre-pumping Alder Springs flow of 8.7 cfs at a temperature of 11° C and a Whychus Creek flow of 10.85 cfs above the spring at a temperature of 26.7° C (Watershed Sciences, 2008). The 0.07° C increase in the temperature of Whychus Creek at Alder Springs as a result of the pumping of the Thornburgh wells is much greater than the "less than 0.01" value calculated by Tetra Tech. This is due to the error in the first bulleted item discussed above. The Thornburgh mitigation plan provides no mitigation for Whychus Creek.

The general form of the equation used to calculate the temperature resulting from the mixing of two flows of water is, $T_{resulting} = \frac{(T_{stream} \times Q_{stream}) + (T_{inflow} \times Q_{inflow})}{(Q_{stream} + Q_{inflow})}$

$T_{resuslting}$:	Stream temperature after mixing
T_{stream} :	Stream temperature
Q_{stream} :	Stream flow rate
T_{inflow} :	Inflowing water temperature
Q_{inflow} :	Inflow rate.

Newton Consultants, Inc July 15, 2008 Response Letter

The statement in the bulleted item on bottom of page 2 of the Newton Consultants letter says that "much of the water for domestic, municipal and quasi-municipal purposes returns to ground water via septic systems and sewage treatment systems, and through seepage from landscape irrigation". This is not correct, the DEQ permit for waste treatment requires that waste water be surface applied during the irrigation season and stored in lined lagoons during the non-irrigation season. The intent of the permit and treatment system is to prevent waste water from recharging groundwater and impacting water quality. This is significant because a large portion of the annual 971 acre feet of groundwater withdrawn for quasi-municipal use will end up in the sewage treatment system and thus not recharging groundwater. The consequence is that the proposed mitigation will not fully mitigate impacts to streamflows and fish habitat.

Cumulative Impact

Anne Corcoran Briggs, the hearings officer, asked the following question in her memo date July 7, 2008.

How do I evaluate the broader impacts of the development ascribed to the proposal? For example, the opponents argue that the cumulative impacts must be considered in the wildlife *analysis, but do not explain how those impacts can be quantified against the proposed mitigation.*

The impacts of the Thornburgh resort groundwater withdrawal on the middle Deschutes River and Whychus Creek should be considered in the context of whatever other groundwater permits have been issued but not yet fully developed and the location of their proposed mitigation. The rivers and creeks have not yet seen these impacts, but will. The applicant could determine the relevant groundwater withdrawal volumes from OWRD records and then run the USGS model.

Additionally, the impacts of the Thornburgh resort development on streams, fish and wildlife should be considered in the context of future developments that will also depend on groundwater withdrawals. There are proposed destination resorts in various stages of planning that would likely also impact the middle Deschutes River and Whychus Creek. These include the following:

- Ponderosa Land & Cattle Company on Green Ridge, 2,350 homes, two golf courses, 150 overnight accommodations, water right 7,550 af, 10.4 cfs
- Aspen Lakes expansion as a destination resort
- Skyline Forest development of potentially 1,000 homes and a golf course
- Thornburgh II potentially needing an additional 2,100 af, 2.9 cfs

The cumulative impact of these developments will likely have significant impacts on streamflow and temperature. Groundwater pumping scenarios for these developments could be modeled using the USGS groundwater flow model to evaluate the cumulative impact to streamflow and water temperature.

Given that it will take 20 to 30 years for the impact of the Thornburgh groundwater pumping to be fully realized, it is critical that the cumulative impact of this particular groundwater use and future groundwater uses be critically evaluated. The failure to mitigate the impact of each new groundwater withdrawal fully will add up to substantial loss of fish and wildlife resources. It would be difficult and costly to recover the lost resources.

Sincerely,

Mark Yinger, R.G.
Hydrogeologist

Attachments:

ODWF letter dated June 13, 2008

References:

Gannett, Marshall and others, 2001, Ground-Water Hydrology of the Upper Deschutes Basin, Oregon, USGS Water-Resources Investigation Report 00-4162.

Gannett, Marshall and Lite, Kenneth, 2004, Simulation of Regional Ground-Water Flow in the Upper Deschutes Basin, Oregon, USGS Water Resources Investigation Report 03-4195.

OWRD, 2005, Public Interest Review For Ground Water Application, prepared by Kenneth Lite for the application G-16385.

Tetra Tech EC, Inc., May 2008, Evaluation of the Proposed Thornburgh Resort Project Impact on Hydrology and Fish Habitat, prepared for Thornburgh Resort Co. LLC.

Watershed Sciences and MaxDepth Aquatics, 2008, Deschutes River, Whychus Creek and Tumalo Creek Temperature Modeling, prepared for the Oregon Department of Environmental Quality.

Yinger, Mark and Strauss, Laura, 2008, A Case Study: Thornburgh Resort Water Resources Impact Evaluation Upper Deschutes Basin, Oregon, for Steve Munson and Sandy Lonsdale, Native Restoration Fund, Vulcan Power Co.

Groundwater & Environmental Consultants
Mark Yinger Associates
69860 Camp Polk Road, Sisters, OR 97759 - 541-549-3030

June 13, 2008

Steve Munson
Vulcan Power Company - Native Restoration Fund
345 SW Cyber Drive, Suite 103
Bend, OR 97702

Ref: Review of portions of the Thornburgh Final Master Plan Application, Deschutes County file number M-07-2.

Dear Mr. Munson:

I have reviewed two portions of the Thornburgh Final Master Plan Application. These are the *Thornburgh Resort Fish and Wildlife Mitigation Plan Addendum relating to Potential Impacts of Ground Water Withdrawals on Fish Habitat* prepared by Newton Consultants (Newton, 2008) and the *Revised Well Indemnification Plan* contained in Exhibit 3.

Background

The Thornburgh Resort development would use groundwater to supply all uses. These uses include: irrigation of three golf courses, landscaping irrigation, maintenance of artificial lakes and potable water. The annual volume of groundwater withdrawn from new wells would be 2,129 acre feet (af) and of this amount 1,356 af must be mitigated for impacts to streamflow. The basis for the mitigation requirement for new groundwater withdrawals is the established principle that virtually all water pumped from the Deschutes Formation aquifer and consumed is water that will not discharge to streams in the upper Deschutes River basin (Gannet and others, 2001, and Gannett and Lite, 2004).

In the summary and conclusions section of the U.S. Geological Survey (USGS) report, *Ground-Water Hydrology of the Upper Deschutes Basin, Oregon*, the following conclusion is stated:

> "Groundwater and surface water are, therefore, directly linked, and removal of ground water will ultimately diminish streamflow." (Gannett and others, 2001).

The questions are where will the streamflow diminishment occur and what resources will be impacted as a result of the Thornburgh development. To address the first question we used the numerical groundwater flow model developed jointly by the USGS and Oregon Water Resources Department (OWRD) and simply added to the model input the pumping of the six proposed Thornburgh wells. Based on the model output the primary stream reaches with diminished flow would be the Deschutes River from Odin Falls to the mouth of Whychus Creek and lower Whychus Creek (Yinger and Strauss, 2008). In these areas cold groundwater discharge from springs and seeps is critical to bull trout and native redband trout habitat and unique riparian ecology. The cold water of lower Whychus Creek is also critical to the successful re-introduction of Chinook salmon and steelhead.

The Thornburgh developer proposes to mitigate its impact on streamflow with a combination of transferring irrigation water rights on Deep Canyon Creek to instream flow rights, the purchase of 100.7acres of water right from the McCabe Family Trust and the remainder from Central Oregon Irrigation District (COID) water rights. The developer claims that their mitigation plan will fully mitigate negative impacts to habitat and fishery resources.

Comments on Fish and Wildlife Mitigation Plan

The following are my comments on the *Thornburgh Resort Fish and Wildlife Mitigation Plan Addendum relating to Potential Impacts of Ground Water Withdrawals on Fish Habitat* in the Thornburgh Final Master Plan (FMP, 2008). The following comments are organized using the headings in the above referenced document.

II. BACKGROUND (page 1)
The statement to the effect that the use of groundwater is expected to indirectly impact flows of the Deschutes River is incorrect. The pumping of the Thornburgh wells will directly impact flow of the Deschutes River. It has been well established that in the upper Deschutes Basin groundwater that is withdrawn and consumed is groundwater that does not discharge to streams.

III. D. 1. OWRD Mitigation for Phase A
Big Falls Ranch Water Right (page 5)
No evidence is given to support the expectation that an acre of irrigation water right should be converted at the rate of 1.8 acre feet of mitigation water. No evidence is given as to the volume of irrigation water actually applied annually per acre for the 464.9 acres.

No evidence is given that the 464.9 acres of Big Falls Ranch irrigation water rights on Deep Canyon Creek are valid water rights. No proof is given that all of the 464.9 acres have been irrigated within the last five years (ORS 540.610). It is apparent in a June 2005 color aerial photograph that significant portions of the acreage have not been irrigated (USGS, 2005). In fact, some areas bordering pivots that are claimed as irrigated acres appear to have been fallow for some time.

The claim that the initial 175 acres of irrigation water right transferred to instream for Phase A will result in 2.07 cfs from Deep Canyon creek is not supported with any data, evidence or explanation. No data or evidence is given to substantiate what the flow volume of Deep Canyon Creek actually is.

III. D. 2. OWRD Mitigation for Phase B/Full Build-Out (page 6)
Again the validity of an additional 289.9 acres of Big Falls Ranch irrigation water rights on Deep Canyon Creek is not substantiated. No evidence is given that all of these acres have been irrigated within the last five years.

No evidence is given that the 100.7 acre McCabe water right is valid. The particular water right is not identified.

No specifics are given on the COID mitigation water which is apparently based only on an expectation of availability of water due to conversion of land to urban uses.

III, E. Summary of OWRD Mitigation Plan (page 6)
The claim that mitigation will result in 5.5 cfs of flow from Deep Canyon Creek during the irrigation season is not supported with evidence. No evidence is given that the creek is actually capable of a flow of 5.5 cfs. No evidence is given that the irrigation pump or pumps are capable of pumping 5.5 cfs. It is possible that the Big Falls Ranch water rights exceed the capacity of the creek.

The claim is made that the Big Falls Ranch mitigation water from Deep Canyon Creek will be cool water. No evidence is given to support this claim. What is the water temperature of the creek now and how does it vary seasonally and along its course?

IV. FISH HABITAT POTENTIALLY AFFECTED BY GROUND WATER USE (page 7)
It is implied that because the state requires mitigation there will be no impact to streamflow and stream temperature due to the Thornburgh groundwater withdrawals. The state's mitigation requirement is no assurance that this particular impact will be mitigated by this particular plan. The mitigation plan is Thornburgh's plan, not the state's, and Thornburgh must present clear and convincing evidence that their mitigation plan will actually mitigate their impacts on streamflows, water temperature in the streams, fish and critical fish habitat. This evidence is not given.

The impact to lower Whychus Creek cold water springs and seeps is dismissed in the mitigation plan. Our groundwater modeling of the impacts of the Thornburgh withdrawals show that there will be reduced discharge of cold groundwater to the lower reach of Whychus Creek (Yinger and Strauss, 2008). We used the USGS-OWRD developed groundwater flow model with no modifications other than the added stress of the Thornburgh groundwater withdrawals. No evidence is given to support the Thornburgh position that the impacts will occur only on the Deschutes River.

The modeled reduction in cold groundwater discharge to lower Whychus Creek is 106 af annually. This reduction in cold spring water discharge is not a negligible impact. The ecology of Whychus Creek is cold groundwater dependent.

The statement that "...NCI (Newton Consultants Inc.) determined the potential temperature impacts attributable to the project (Thornburgh) are expected to be slight and below levels that can be effectively measurable." is not supported with any evidence. On what basis did NCI make this determination?

There is also some discussion of ODFW "Habitat Categories." The impacted reaches of the Deschutes River and Whychus Creek should be considered Habitat Category 1 as defined in Oregon Department of Fish and Wildlife (ODFW) administrative rule (OAR 635-415-0025). The cold water springs and seeps are irreplaceable and essential for fish and wildlife and a unique ecology. The ODFW's mitigation goal is no loss of habitat. It does not allow dismissal of impact based on arguments that the impact will be negligible or un-measurable. Nor does ODFW habitat mitigation policy specifically allow impact to occur in one area in exchange for improvements in another area.

V. C. Elimination of Existing Irrigation Pond (page 9)
The statement is made to the effect that Thornburgh will work with Big Falls Ranch to remove the pond at the point of diversion (near the mouth of Deep Canyon Creek). Notes on Figures 3 and 4 of the mitigation plan state that a second pond located approximately 1,800 feet upstream on Deep Canyon Creek will also be removed. However, the upstream pond is located on property owned by Nolan Weigand. Will this property owner allow the pond to be removed? To realize a lower temperature for the creek water both ponds must be removed.

V. E. Funding for Thermal Modeling (page10)
The mitigation plan characterizes the proposal to provide $10,000 for completion of a stream temperature model for Whychus Creek as enhancement and part of its mitigation "package". The completion of this model and its use provides no mitigation of the impacts the Thornburgh development will have on reaches of the Deschutes River and Whychus Creek.

VII. CONCLUSIONS
The statement that "...potential for loss of habitat due to reduced surface water flows was quantified in connection with the OWRD review of Thornburgh's application for a water right." is not supported with any evidence. As pointed out earlier, just because OWRD rules say you will fully mitigate consumptive use of groundwater does not mean this particular plan fully mitigates Thornburgh's impacts.

Comments on Well Indemnification Plan

The following are my comments on the *Revised Well Indemnification Plan*, Exhibit 3 of the Thornburgh Final Master Plan application.

The Probability of Interference is High

In the second paragraph of the introduction of the indemnification plan, statements are made that based on Newton Consultants original hydrology report for Thornburgh (Newton, 2005) and OWRD water rights application there will no interference with existing wells. Newton's original hydrology report failed to investigate the history of wells in the vicinity of the proposed development. It is standard practice when evaluating the impact of new large production wells to investigate the history of existing wells in the vicinity of the proposed wells. In our evaluation of the impacts of the Thornburgh development on water resources we did this basic research (Yinger and Strauss, 2008). We found that in the area of the Eagle Crest Resort, located just east of the proposed development, that there are 13 wells that have been deepened between 2001 and 2007. The documented water level decline in these wells has been as great as 42 feet. It is reasonable to conclude that the pumping of the large production wells at Eagle Crest has drawn down water levels in wells in the vicinity of this resort. Further, it is reasonable to conclude that the pumping of the six Thornburgh wells will only accelerate the decline of water levels in existing wells in the area and expand the area of water level decline associated with the Eagle Crest Resort.

Our modeling of water levels in response to the pumping of the Thornburgh wells reveals that the pumping of deep Thornburgh wells (model layer 7) will cause declines in water levels of much shallower wells (Yinger and Strauss, 2008). Newton's statement "...that because of aquifer characteristics, depth, and location of Thornburgh's proposed wells, the new groundwater use was not expected to cause interference with other existing ground water uses (wells)" is not supported by the facts. It is clear that the effects of the pumping of deep wells are not isolated from existing shallower wells.

Radius of Well Indemnification

No justification is given to support a two-mile radius limit to indemnify existing wells from impact due the pumping of the Thornburgh wells. The impacted area is certain not to be circular. Based on the impact of the Eagle Crest wells and low permeability of the core of the Cline Buttes rhyolite dome the impacted area will likely be elongated in the north-south direction (Yinger and Strauss, 2008). The radius should be increased to 3 miles to be conservatively protective.

The plan does not define from where the radius of indemnification will be measured. Each new Thornburgh well should be at the center of a 3-mile radius of indemnification.

Duration of Indemnification Agreements

The five year duration of the indemnification agreements is too short. The USGS simulations for pumping wells in the Redmond area indicate that most of the impact on water levels occurs 7 to 10 years after the start of pumping (Gannett and Lite, 2004). The duration of the indemnification agreements should extend for ten years past the completion of the development.

Conclusions

I have pointed out that there are numerous statements and conclusions in the Thornburgh fish and wildlife mitigation plan addendum that are not supported with evidence. The plan cites no references. The claim that this particular fish and wildlife mitigation plan completely mitigates negative impacts to these resources is not credible.

The well indemnification plan has serious shortcomings.

Sincerely,

Mark Yinger, R.G.
Hydrogeologist

Attachment: Summary Table Diminished Streamflow, Model Results for Scenario 1 and Scenario 2, and map of reaches

References:

Gannett, Marshall and others, 2001, Ground-Water Hydrology of the Upper Deschutes Basin, Oregon, USGS Water-Resources Investigation Report 00-4162.

Gannett, Marshall and Lite, Kenneth, 2004, Simulation of Regional Ground-Water Flow in the Upper Deschutes Basin, Oregon, USGS Water Resources Investigation Report 03-4195.

Newton, David, 2005, Hydrology Report Water Supply Development Feasibility Proposed Thornburgh Resort, Deschutes County, Oregon, for Thornburgh Resorts, LLC.

Newton, David, 2008, Thornburgh Resort Fish and Wildlife Mitigation Plan Addendum Relating to Potential Impacts of Ground Water Withdrawals on Fish Habitat, Newton Consultants, Inc. in Thornburgh Final Master Plan.

Strauss, Laura, June 6, 2008, personal communications.

Watershed Sciences, 2007, Deschutes River, Whychus Creek and Tumalo Creek Temperature Modeling, for Oregon Department of Environmental Quality.

Yinger, Mark and Strauss, Laura, 2008, A Case Study: Thornburgh Resort Water Resources Impact Evaluation Upper Deschutes Basin, Oregon, for Steve Munson and Sandy Lonsdale, Native Restoration Fund, Vulcan Power Co.

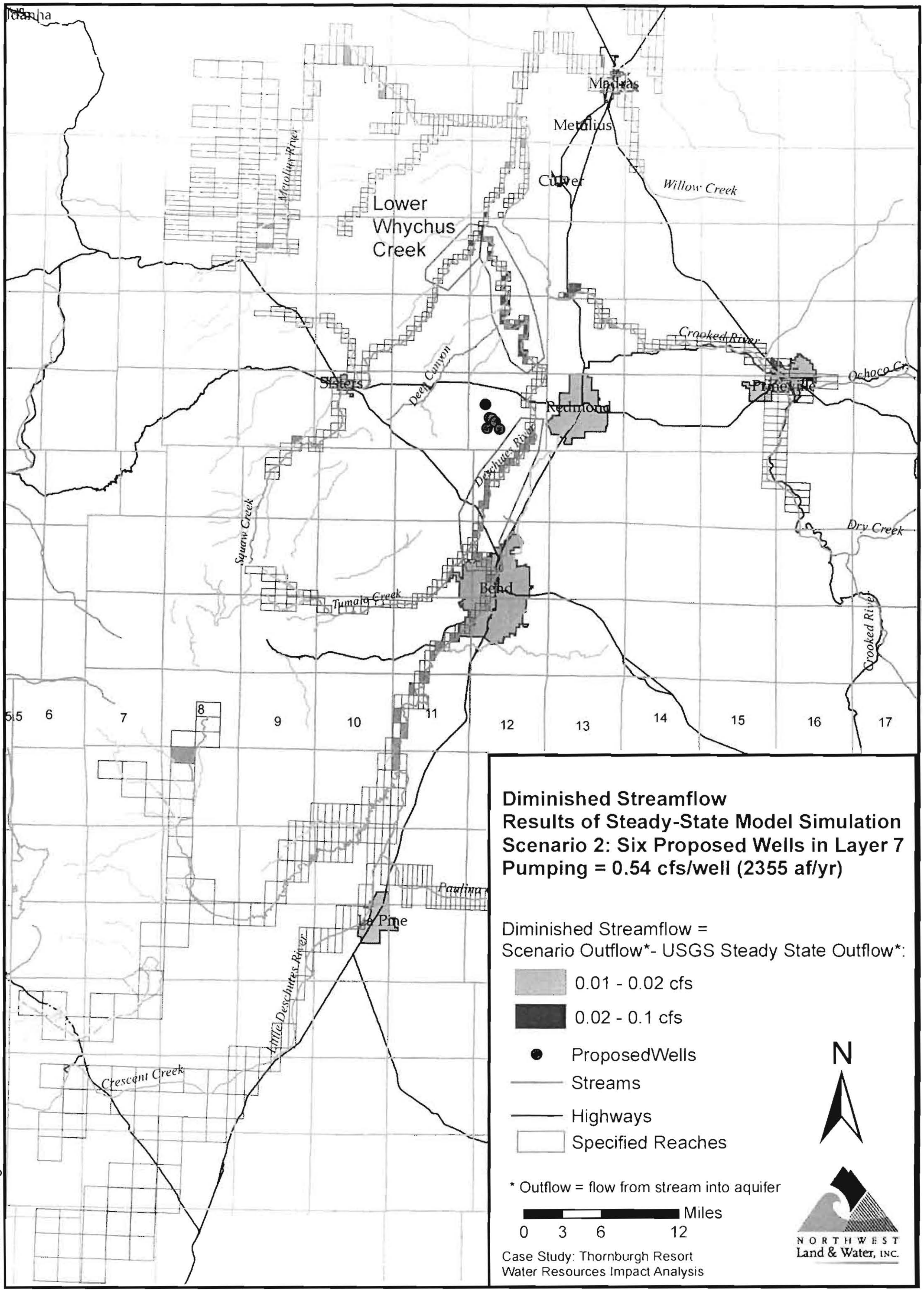
Summary of Diminished Streamflow, Model Results for Scenario 1 and Scenario 2

Reach	Diminished Streamflow, cfs			
	Scenario 1	as percent of total pumping	Scenario 2	as percent of total pumping
Bend to River Mile 149	0.681	21%	0.299	9%
Odin Falls to Whychus Creek and Lower Whychus Cree	1.648	51%	1.780	55%
Combined for two reaches	**2.329**	**72%**	**2.079**	**64%**
Total diminished streamflow for stream system	3.090	95.1%	3.240	99.7%

Reach	Diminished Streamflow, cfs			
	Scenario 1	as percent of total pumping	Scenario 2	as percent of total pumping
Lower Whychus Creek	0.143	4%	0.145	4%
Upper Whychus Creek	0.021	1%	0.021	1%
Whychus Creek	**0.164**	**5%**	**0.166**	**5%**
Total diminished streamflow for stream system	3.09	95.1%	3.24	99.7%

Notes:

1) Total pumping is 3.25 cfs for both Scenarios



Scenario2Qavg-newsolver.mxd

Table 6-1. Precipitation Summary Statistics, Water Years 1991 Through 2007 Upper Deschutes Basin, Oregon

Annual Precipitation, in inches						
Water Year	**Bend**	**Brothers**	**Madras**	**Prineville**	**Redmond**	**Wickiup Dam**
1991		7.35	7.79	8.32	5.49	18.36
1992		9.37	9.26	10.32	6.47	17.5
1993	10.37	14.23	17.82	13.82	12.91	28.12
1994	4.98	6.6	6.55	5.36	5.73	10.14
1995	10.63	9.52	16.64	13.06	9.66	23.3
1996	11.46	10.78	15.27	12.4	2.28	29.28
1997	16.42	12.03	19.32	13.54	4.73	24.41
1998	13.06	9.23	15.66	11.86	11.34	26.32
1999	15.7	2.89	10.37	9.2	8.89	22.94
2000	8.01	2.87	10.41	8.15	6.84	14.83
2001	6.81	4.08	7.38	3.82	1.03	13.19
2002	8.04	1.24	6.43	3.47	5.93	17.07
2003	7.92	2.09	8.95	2.85	7.96	14.6
2004	9.69	1.06	14.13	8.93	9.88	19.16
2005	9.83	8.31	9.78	5.46	10.46	14.58
2006	16.85	7.54	13.21	4.22	11.33	26.05
2007	9.66	5.11	7.82	5.79	5.56	16.15
avg 1993-1995*	8.66	10.12	13.67	10.75	9.43	20.52
avg 2001-2007	9.83	4.20	9.67	4.93	7.45	17.26
difference	-1.17	5.91	4.00	5.81	1.98	3.26
difference as % of USGS period	**-13%**	**58%**	**29%**	**54%**	**21%**	**16%**

* period of study of the USGS groundwater model simulation

Table 6-2. Summary of Monthly and Annual Water Use, In Million Gallons, For Selected Public Supply Wells 1997-2006, Upper Deschutes Basin, Oregon

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1997	48.70	45.37	48.34	74.98	150.47	173.31	277.38	156.22	134.55	88.45	52.27	48.31	1298
1998	110.45	89.89	130.99	177.04	193.39	293.80	477.47	482.26	351.49	172.48	171.10	108.39	2759
1999	185.47	138.73	123.66	201.34	330.61	450.20	564.51	432.68	376.28	191.76	181.71	209.00	3386
2000	171.42	171.36	201.36	280.75	367.84	462.59	488.16	505.27	381.49	238.14	172.95	168.56	3610
2001	145.44	136.48	116.56	177.16	457.69	533.45	582.32	708.38	500.54	285.21	177.16	155.44	3976
2002	89.81	77.05	97.86	285.85	443.74	606.04	676.10	637.15	467.53	227.99	111.88	97.97	3819
2003	151.90	142.21	148.65	203.16	411.10	664.23	840.01	722.86	512.59	205.27	196.41	159.95	4358
2004	129.25	126.13	118.63	127.53	138.60	141.37	156.00	157.35	174.28	138.38	117.83	116.18	1642
2005	109.64	75.42	136.56	110.12	297.08	429.21	683.17	776.10	503.73	216.46	81.19	114.46	3533
2006	76.08	66.56	78.21	113.76	299.47	295.07	478.75	506.94	321.16	147.30	80.72	81.91	2546

Note: Years 2004 and 2006 have small totals due to so much missing data
If 2003 data were used in place of the missing 2004 data, 2004 Total would be 4796
If 2005 data were used in place of the missing 2006 data, 2006 Total would be 3891

Table 6-3. Summary of Monthly and Annual Water Use, In Million Gallons, For Selected Private Supply Wells 1997-2006, Upper Deschutes Basin, Oregon

Year	Jan	Feb	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1997	31.00	17.96	15.69	14.62	16.95	19.92	30.50		49.80	62.64	47.51	369
1998	151.71	63.63	52.43	69.91	60.87	61.81	92.06		212.14	275.85	208.69	1429
1999	165.93	63.49	49.62	51.94	56.60	73.26	117.91	183.71	203.01	253.09	212.55	1494
2000	220.84	63.65	63.25	64.26	80.84	104.00	147.87	230.17	337.11	336.95	283.47	2009
2001	200.86	35.78	54.95	47.51	59.50	65.27	118.88	264.46	233.66	237.35	238.19	1614
2002	62.76	30.47	23.93	23.75	31.00	45.59	81.74	4.35	107.52	126.87	108.74	775
2003	382.37	175.92	162.47	154.02	149.85	172.32	282.18	305.86	550.48	686.47	604.77	4093
2004	128.03	93.47	89.36	215.88	202.49	332.06	367.74		351.22	240.12	201.60	2644
2005	71.67	25.10	20.28	20.78	36.04	54.00	62.18	51.96	142.51	156.11	121.62	814
2006	374.04	84.54	63.37	97.24	77.92	102.69	181.66	338.60	376.75	425.63	468.10	2658

Table 6-4. Summary of Annual Water Use, in Million Gallons, For Select Public Supply Wells, Upper Deschutes Basin, Oregon

Public Water Supply Well Name	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
City Bend Rock Bluff No. 2		111.5	111.11	80.62	186.75	119.23	2.73		15.13	
City of Bend Airport Well						3.86	5.91		13.36	
City of Bend Bear Ck Well 1				277.38	216.81	260.55	120.15		247.78	
City of Bend Outback Well 1		72.18	52.97	33.04	76.115	169.71	140.31		74.21	
City of Bend Outback Well 2		83.25	64.5	37.46	102.16	55.74	39.22		115.67	
City of Bend Outback Well 3						146.96	248.35		232.51	
City of Bend Pilot Butte 1 Well		148.8	174.63	196.51	134.73	0	0		105.36	
City of Bend Pilot Butte 2 Well		124.26	131.93	156.02	186.25	208.91	168.26		142.56	
City of Bend Pilot Butte 3 Well					211.49	236.31	187.46		153.76	
City of Bend River !		50.64	60.74		189.71	328.14	327.2		152.73	274.52
City of Bend River 2		156.84	157.84		69.035	149.76	156.75		63.27	154.36
City of Bend Rock Bluff No. 3		66.41	80.15	222.73	37.614	219.95			53.23	
City of Bend Rock Bluff No.1		136.6	134.8	5.1	0	111.14	42.84		148.67	
City of Bend Westwood Well		32.72	56.85	62.25	86.106	108.55	123.84		42.43	
City of Redmond Well 1	164.08	149.41	168.08	101.41	129.10	111.93	133.04		121.78	102.763
City of Redmond Golf Course Well					1.1834			1.5123	0	72.2752
City of Redmond Sewage Effluent Res..		435.22	441.84	509.02	302.1		299.45	658.69		
City of Redmond Sewage WW Treatment		0	441.84	509.02	523.8		637.4	658.69		
City of Redmond Well 2	198.67	186.79	132.52	80.141	161.22	116.85	162.38		183.96	194.795
City of Redmond Well 3 Ind Complex	474.44	504.04	479.43	241.61	560.24	257.32	405.13		396.69	500.454
City of Redmond Well 4 FK Horned Butte	266.97	350.31	281.94	223.04	284.05	276.75	194.16		537.46	483.093
City of Redmond Well 5		0	224.41	667	289.47	683.37	696.99		430.19	463.56

Table 6-4. Summary of Annual Water Use, in Million Gallons, For Select Public Supply Wells, Upper Deschutes Basin, Oregon

Public Water Supply Well Name	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
City of Sisters City Well Nol 1	10.322	5.986	52.423	40.118	74.595	148.43	131.01	144.65	140.05	114.212
City of Sisters H.S. Well No 2	164.73	101.69	93.758	123.21	100.61	50.74	87.331	126.80	91.045	117.630
Terrebonne Water Dist. Well 1	0	22.577	24.657	21.076	23.822	32.072	9.7633	16.972	33.526	26.5970
Terrebonne Water Dist. Well 3					4.1511	14.207	38.692	34.211	37.752	41.6671
Terrebonne Water Dist.Well 2	19.14	19.543	19.543	23.141	24.718	8.4843	0	0	0	0

Table 6-5. Summary of Annual Water Use, in Million Gallons, For Select Private Supply Wells, Upper Deschutes Basin, Oregon

Private Water Supply Well	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Agate--Agate Water Company				9.99	2.92	30.00	420.19			
Avion--Avion Water Company							1382.14	1598.17		1916.98
Chapparral--Avion Water Company	30.27	28.10	34.67	35.46	32.90	35.10	33.21	32.73		30.14
Chocktaw--Agate Water Company				29.74	2.90	4.12	133.04			
Cinder Butte--Avion Water Company	5.52	7.08	7.08	7.31	7.31	7.76	7.81	7.75		9.32
Conestoga-Avion Water Company		1068.87	1088.28	1321.57	1280.01		1443.20			
Crane Water Wonderland	46.62	39.85	47.16	64.69	66.14	71.78	71.78	87.30		45.98
drw Tuscarora - Avion Water Company	4.23	4.58	4.71	6.99	5.08	6.04	6.13	6.05		4.90
Indian Summer--Agate Water Company				5.45	5.98	5.34	43.13			
Merganser Water Wonderland	1.35		5.49	0.00			3.18	0.00		30.60
Null La Casa Mia Association	1.28	1.21	1.25	1.38	1.35	1.41	1.67		1.67	0.94
Null--Avion Water Company					3.27					
Odin Falls - Avion Water Company	1.93	2.50	3.02	7.31	4.32	4.94	6.04	6.53		10.63
Red Cloud- Avion Water Company	13.38	15.30	20.71	21.10	21.91	24.89	26.45	26.23		0.00
River Bluffs--Agate Water Company				5.27	0.00	0.00	0.00			
School Well Laidlaw Water District		1.39	1.55	0.76		6.87				
SeeversWater Wonderland	13.95	14.26	14.65	14.51	17.92	23.14	21.45	24.28		21.46
Shoshone--Agate Water Company				7.00	0.33	0.37	4.22			
Tetherow Crossing- Avion Water Company	9.03	10.30	12.42	12.96	12.95	14.14	14.73	14.08		13.18
Well 1 Home Roats Water System Inc.	39.75	47.61	47.08	40.33		48.93	29.23	24.13	31.54	0.00
Well 10 Pinebrook Roats Water System	0.08	0.00								0.00
Well 2 Cline Butte Utility Co								106.46	85.77	83.36

Table 6-5. Summary of Annual Water Use, in Million Gallons, For Select Private Supply Wells, Upper Deschutes Basin, Oregon

Private Water Supply Well	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Well 2 Home Roats Water System	15.31	16.63	17.01	19.59		14.67	2.52	2.88	2.62	0.00
Well 3 Cline Butte Utility Co								61.45	63.79	82.54
Well 3 Pinebrook Roats Water System	10.69	11.81	11.94	14.01		17.14	14.92	15.65	14.08	0.00
Well 4 Pinebrook Roats Water System	77.08	67.66	70.49	94.02		100.63	115.82	114.84	112.75	0.00
Well 5 Woodside Roats Water System	45.73	35.97	40.41	35.34		49.30	42.48	42.25	36.97	0.00
Well 6 Cline Butte Utility Co				100.23	115.84	109.76	103.84	113.17	105.21	113.31
Well 6 Woodside Roats Water System								0.00	0.00	0.00
Well 7 Cline Butte Utility Co				0.00	0.00	68.02		21.17	19.70	19.94
Well 7 Woodside Roats Water System	19.26	22.03	19.21	17.09		9.92	7.80	28.36	28.98	0.00
Well 8 Cline Butte Utility Co				67.84	25.57	44.81	75.98	78.58	64.57	69.15
Well 8 Woodside Roats Water System	28.72	29.00	41.51	61.90		69.49	51.84	52.33	41.59	0.00
Well 9 Cline Butte Utility Co								136.81	179.17	196.51
Well 9 Pinebrook Roats Water System							22.53	35.26	25.34	0.00
Wild R Avion Water Co	0.32									
Wild R - Avion Water Company	4.54	4.67	5.56	6.73	7.42	6.77	8.09	7.42		8.63

Table 7-1. Summary of Diminished Streamflow, Model Results for Scenario 1 and Scenario 2

Reach	Diminished Streamflow, cfs			
	Scenario 1	as percent of total pumping	Scenario 2	as percent of total pumping
Bend to River Mile 149	0.68	21%	0.30	9%
Odin Falls to Whychus Creek and Lower Whychus Creel	1.65	51%	1.78	55%
Combined for two reaches	**2.33**	**72%**	**2.08**	**64%**
Total diminished streamflow for stream system	3.09	95.1%	3.24	99.7%

Notes:

1) Total pumping is 3.25 cfs for both Scenarios

Table 8-1.
Summary of Ground Water Rights Permits and Granted Water Use Per Year Since 1/1/1998, Within USGS Study Area, Upper Deschutes Basin, Oregon

Year Of Right Date	Number of Permits	Sum of Maximum Granted Use, cfs
1998	14	10.70
1999	10	1.91
2000	4	1.43
2001	3	5.37
2002	7	9.59
2003	3	11.78
2004	16	0.78
2005	19	2.31
2006	2	0.28
		Total = 44.13

d:\Thornburgh\WaterRights\DeschutesWaterRights.mdb:rptSummary of Permits By Year.rpt

Table 8-2.
Summary of Ground Water Rights Applications and Requested Water Use Per Year Since 1/1/1998, Within USGS Study Area, Upper Deschutes Basin, Oregon

Year Of Priority Date	Number of Applications	Sum of Maximum Requested Use, cfs
1998	9	26.13
1999	7	27.47
2000	2	0.07
2001	3	0.51
2002	2	1.40
2003	3	0.72
2004	8	2.41
2005	7	32.67
2006	12	13.31
2007	19	71.31

d:\Thornburgh\WaterRights\DeschutesWaterRights.mdb:rptSummary of Applications By Year rpt

Table 8-3.
Summary of Surface Water Rights Permits and Granted Water Use Per Year Since 1/1/1998, Within USGS Study Area, Upper Deschutes Basin, Oregon

Year Of Right Date	Number of Permits	Sum of Maximum Granted Use, cfs
2005	2	0.14
2007	1	2.64

Table 8-4.
Summary of Surface Water Rights Applications and Requested Water Use Per Year Since 1/1/1998, Within USGS Study Area, Upper Deschutes Basin, Oregon

Year Of Priority Date	Number of Applications	Sum of Maximum Requested Use, cfs
2007	10	0.07

Table 9-1

Summary of Number of Wells Deepened since 1980 in the Vicinity of Thornburgh/Redmond By Township and Range

Township - Range	2000-present	1995-1999	1990-1994	1985-1989	1980-1984	Totals
T 14 S – R 12 E	8	6	1	3	4	22
T 15 S – R 11 E	8	9	15	5	3	40
T 15 S – R 12 E (Eagle Crest)	17	2	0	4	4	27
T 15 S – R 13 E (Redmond)	23	11	3	0	7	44
T 16 S – R 11 E (East half)	9	6	7	0	4	26
T 16 S – R 12 E	17	13	9	4	8	51
Totals	82	47	35	16	30	**210**

Source: Oregon Water Resources Department Well Log Database

Base map taken from Ground-Water Hydrology of the Upper Deschutes Basin, Oregon, Water-Resources Investigations Report 00-4162. Proposed Thornburgh Resort boundaries taken from Hydrology Report Water Supply Development Feasibility Proposed Thornburgh Resort DCC 18.113.050, 2/2/2005.

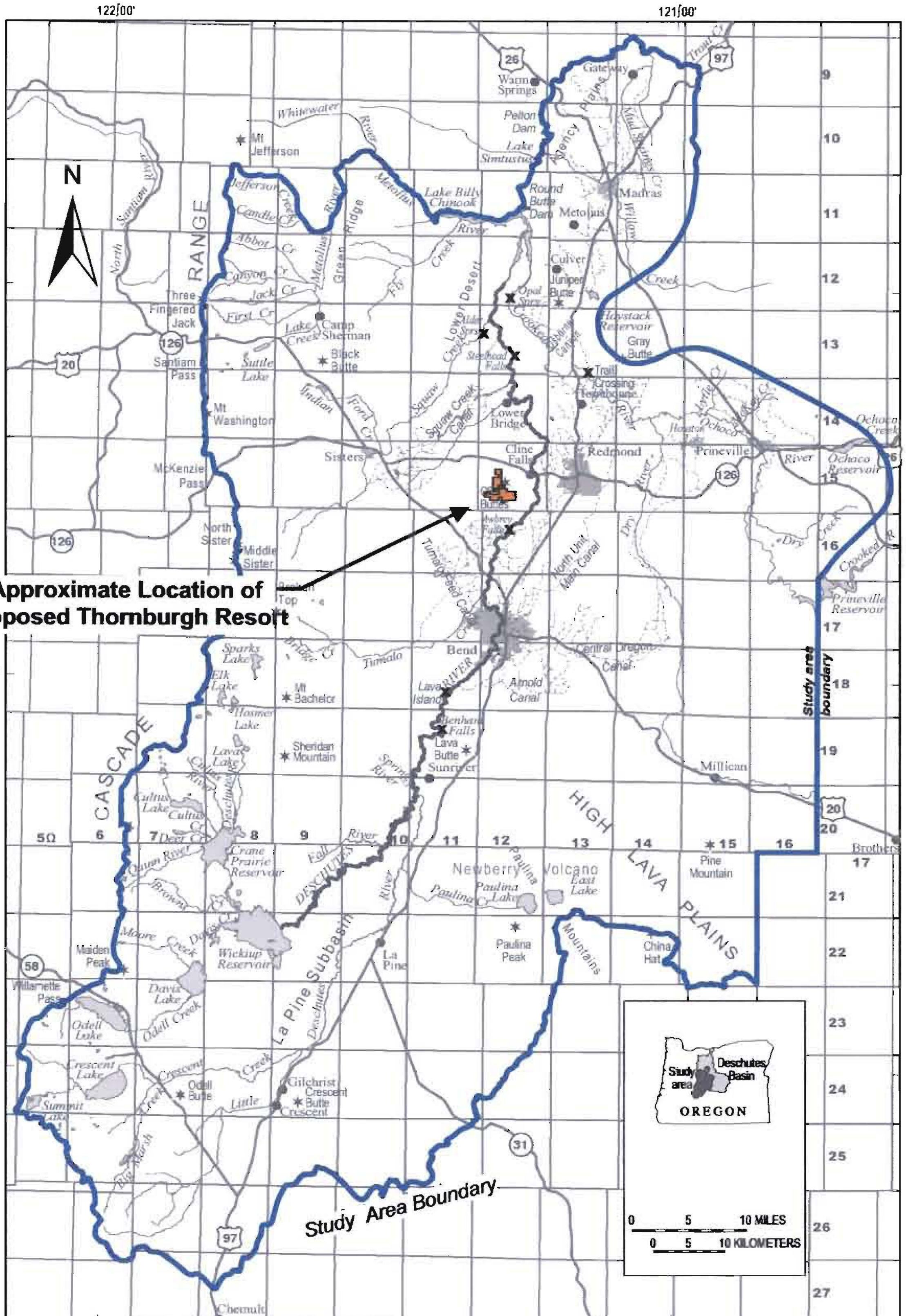


Figure 2-1
USGS Study Area

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Base map taken from USFS Deschutes National Forest map. Reference: Thornburgh Resort and proposed wells locations taken from Hydrology Report, Water Supply Development Feasibility DCC. 18.113.050, 2/ 2,/2005.

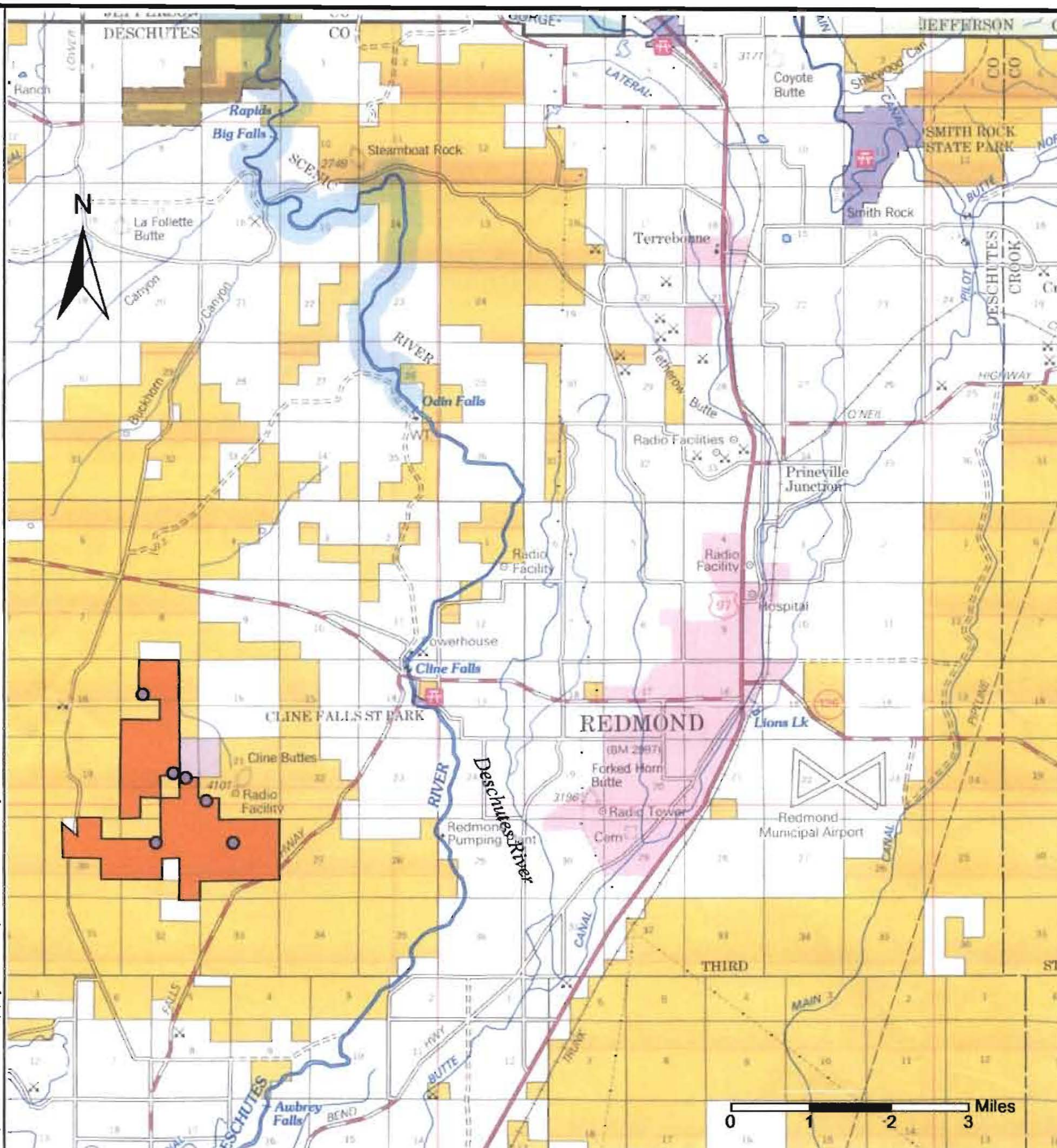

Figure 2-2
Location Map

- Bureau of Land Management
- State Lands
- Private & Other Ownership
- Thornburgh
- O Proposed Thornburgh Well Location

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Water Resources Impact Evaluation

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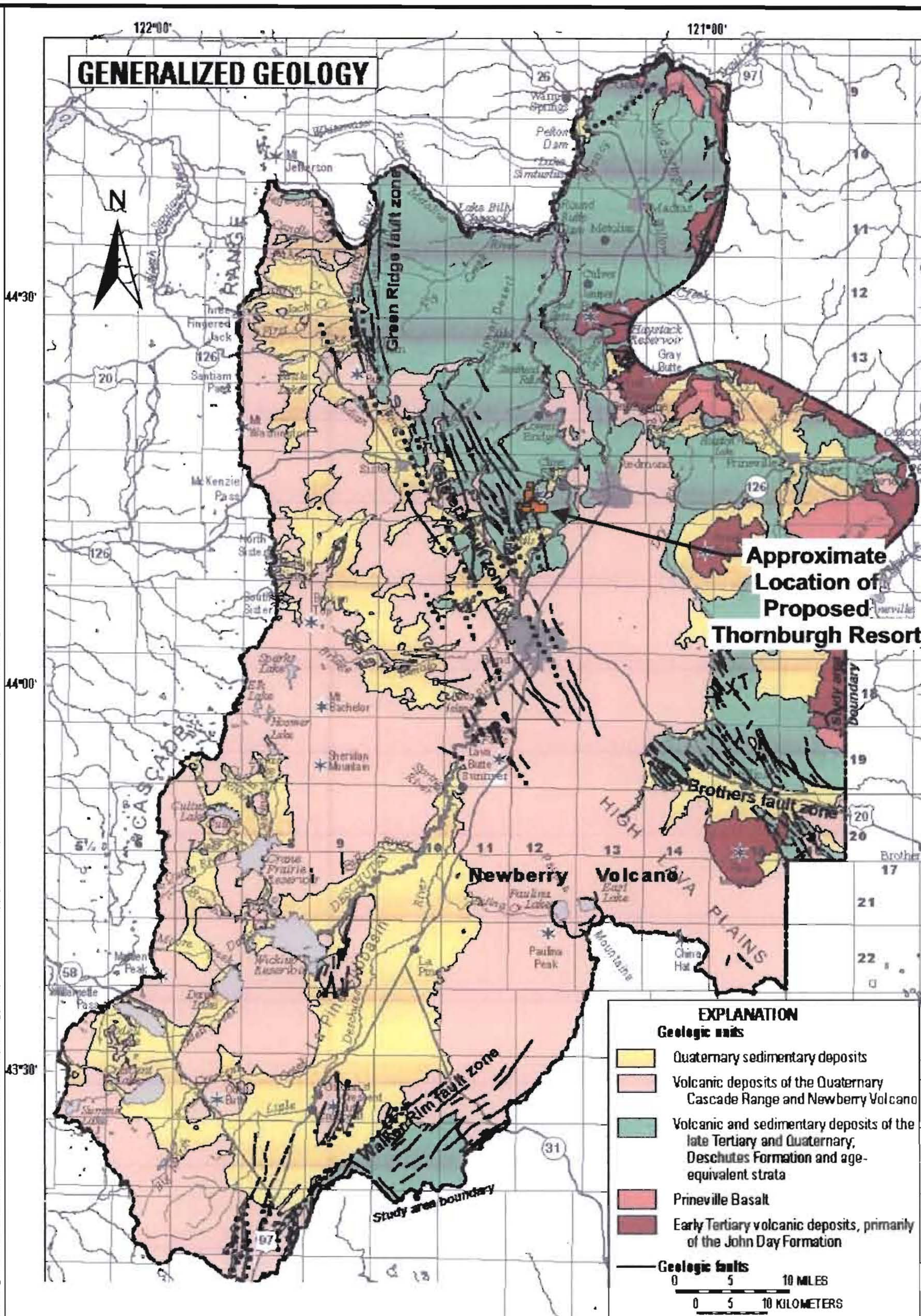

Reference: Simulation of Regional Ground-Water Flow in the Upper Deschutes Basin, Oregon. U.S. Department of the Interior, U.S. Geological Survey, Water-Resources Investigations Report 03-4195. Proposed Thornburgh Resort and Eagle Crest Resort boundaries taken from Hydrology Report Water Supply Development Feasibility Proposed Thornburgh Resort DCC 18.113.050, 2/2/2005.

Figure 5-1
Generalized Geologic Units of the Upper Deschutes Basin

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Water Resources Impact Evaluation

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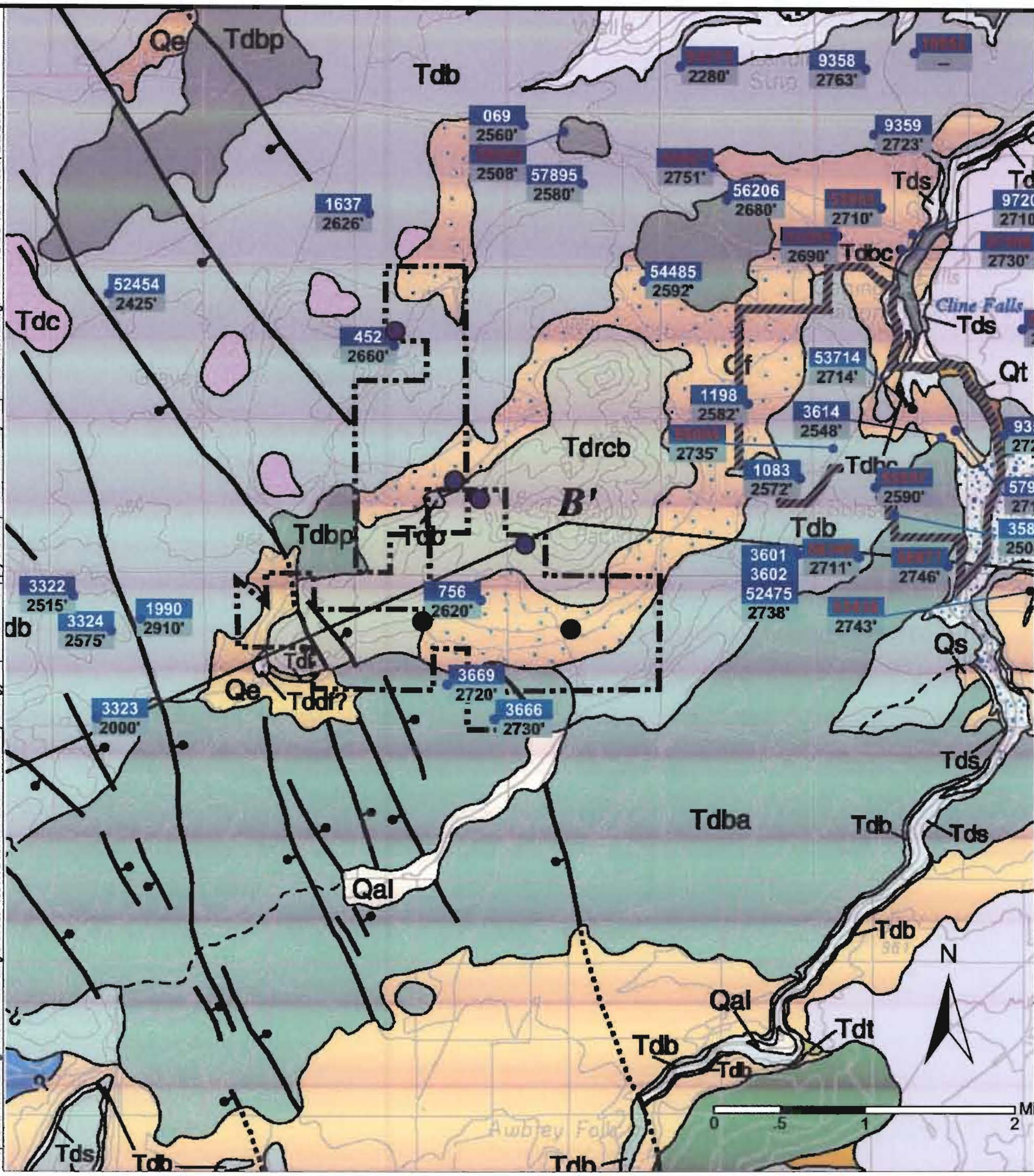
Reference: USGS Geologic Map of the Bend 30- X 60-Minute Quadrangle, Central Oregon. By Sherrod, Taylor, Ferns, Scott, Conrey & Smith. 2004. Geologic Investigations Series Map I-2683.
Proposed Thornburgh Resort and Eagle Crest Resort boundaries taken from Hydrology Report Water Supply Development Feasibility Proposed Thornburgh Resort DCC 18.113.050, 2/2/2005.



Deschutes Formation

Qal	Alluvium
Qe	Eolian deposits
Qt	Talus & colluvium
Qs	Sand & gravel
Qf	Alluvuial sand deposits
Tds	Sedimentary rocks & deposits
Tdb	Basalt
Tdbp	Porphyritic basalt
Tdbc	Basalt of Cline Falls
Tdba	Basaltic andesite
Tdt	Ash-flow tuff
Tddf	Debris-flow deposits
Tdrcb	Rhyolite of Cline Buttes
Tdc	Cinder deposits

Approximate location Thornburgh Resort

Approximate location Eagle Crest Resort

56877 — Deschutes County well log number & approximate location

2746' — Approximate static water level elevation based on well log

Deepened well log number

Approximate location of proposed Thornburgh well

Figure 5-2
Detailed Geologic Map & Well Locations Cline Buttes Area

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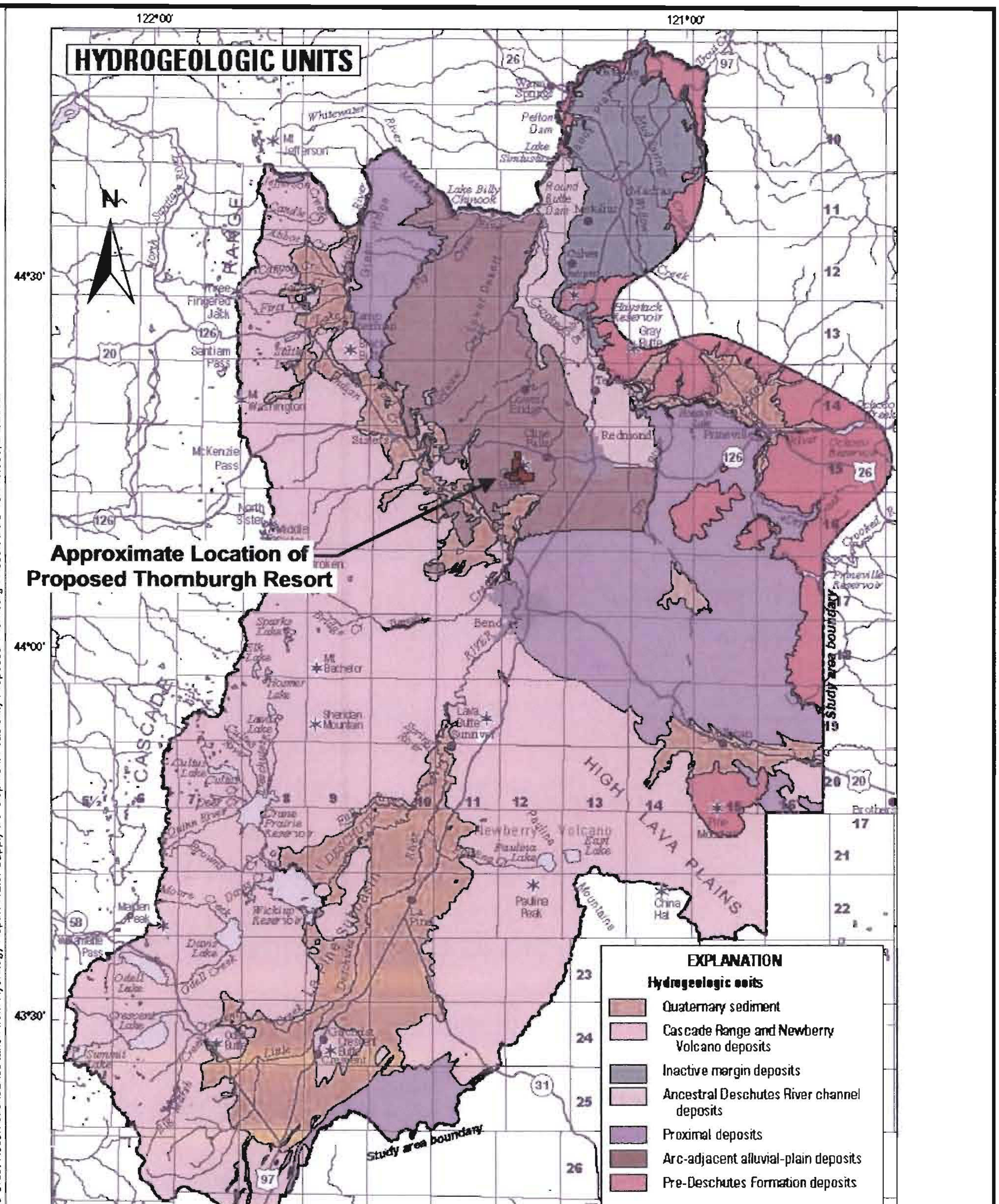

Reference: Simulation of Regional Ground-Water Flow in the Upper Deschutes Basin, Oregon. U.S. Department of the Interior, U.S. Geological Survey, Water-Resources Investigations Report 03-4195. Proposed Thornburgh Resort and Eagle Crest Resort boundaries taken from Hydrology Report Water Supply Development Feasibility Proposed Thornburgh Resort DCC 18.113.050, 2/2/2005.

Figure 5-3
Generalized Hydrogeologic Units of the Upper Deschutes Basin

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Water Resources Impact Evaluation

Mark Yinger Associates

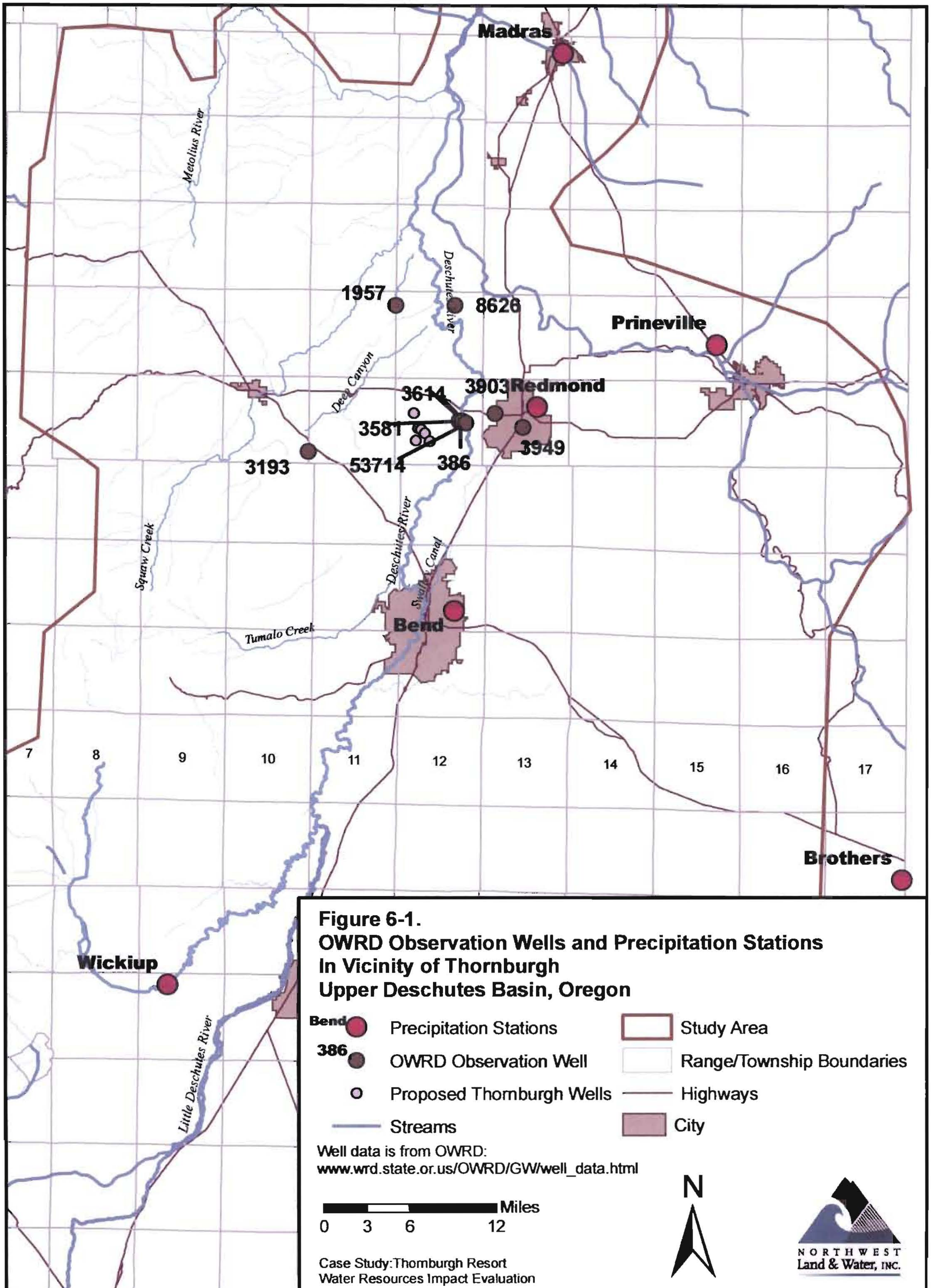

Figure 6-1.
OWRD Observation Wells and Precipitation Stations
In Vicinity of Thornburgh
Upper Deschutes Basin, Oregon

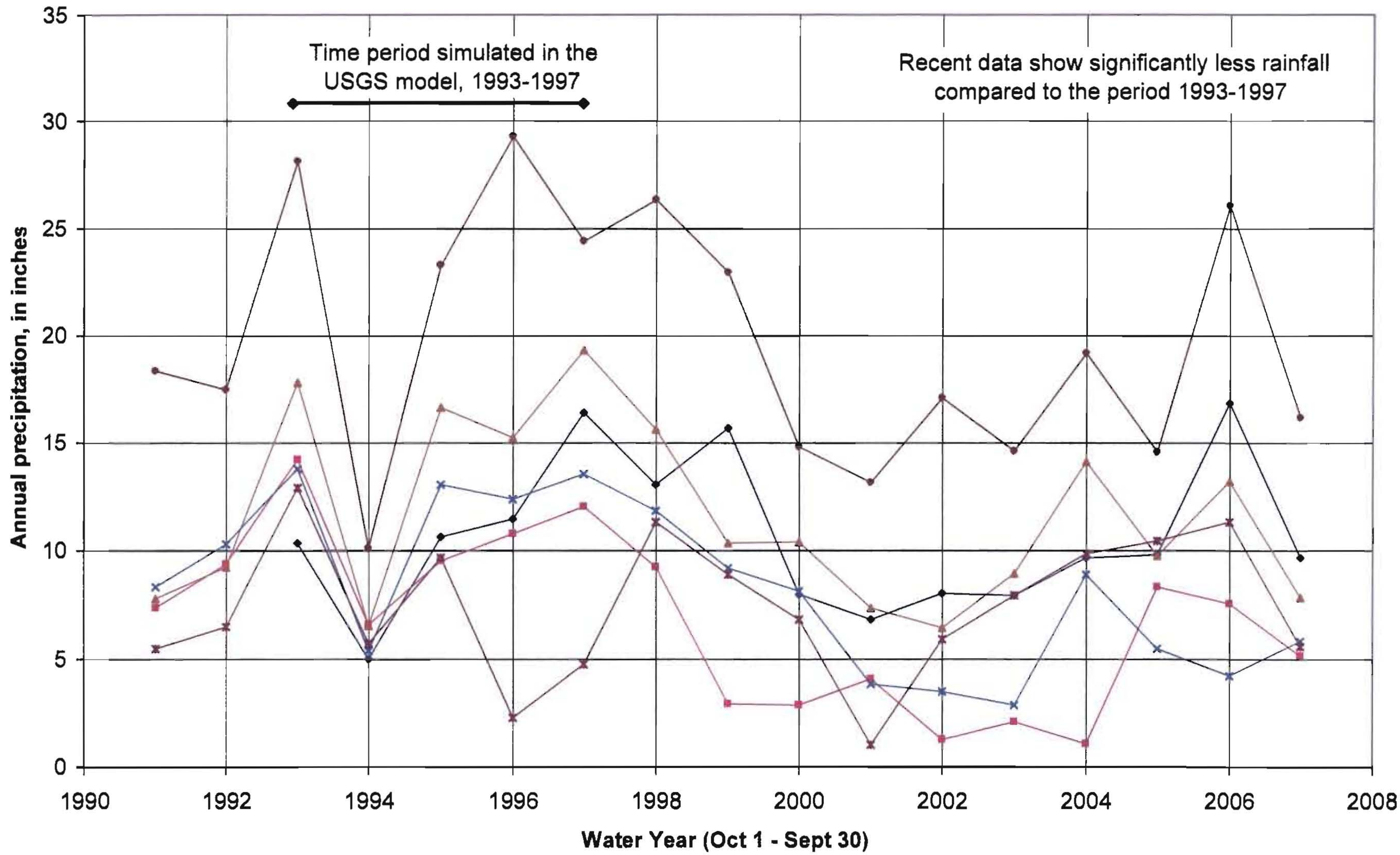

Figure6-2. Annual Precipitation at Six Sites in Upper Deschutes Basin

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d:\projects\Thornburgh\precipitation\ppt Graph and stats.xls;Fig 6-2 Annual Precipitation

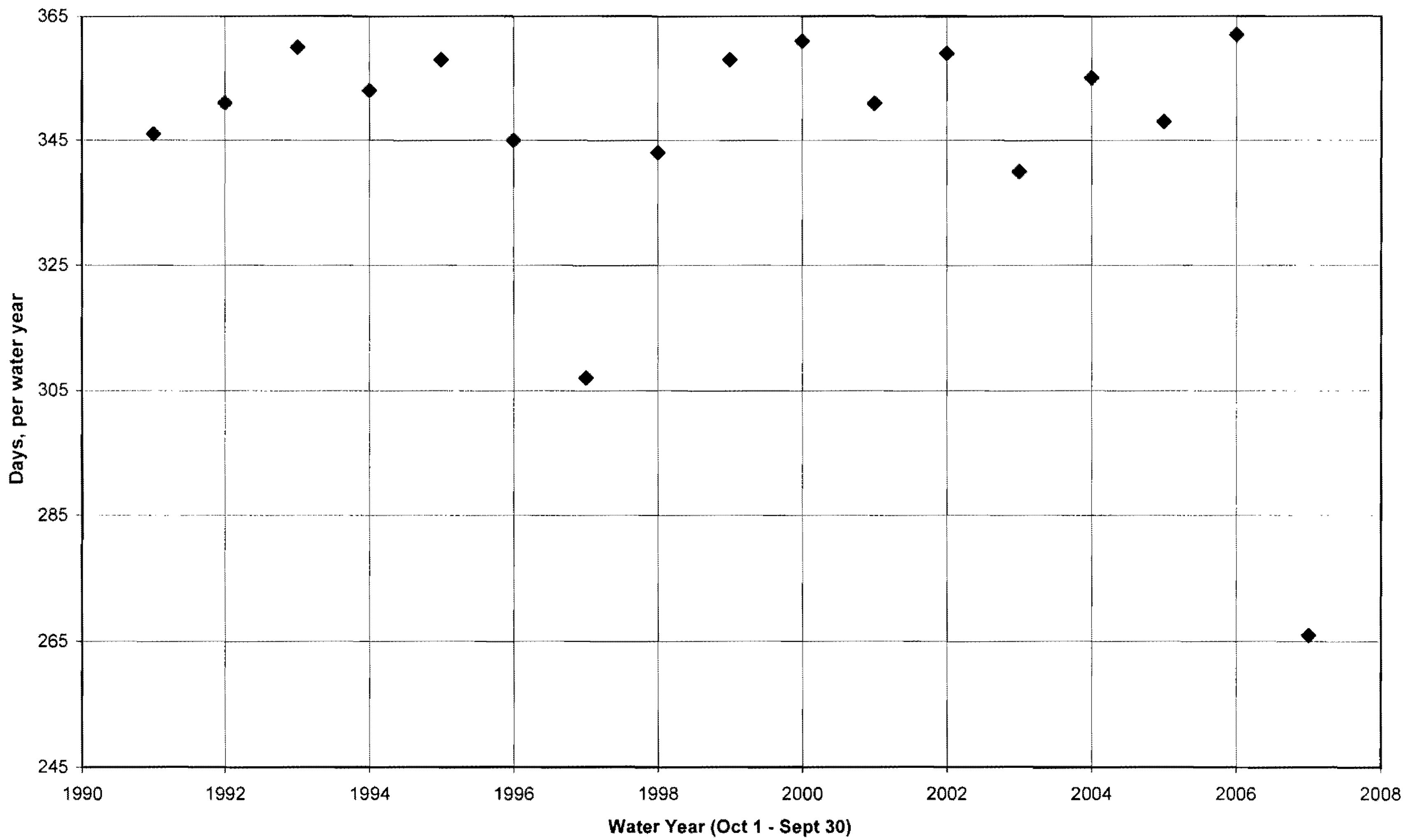

Figure 6-3. Days of Snow Per Water Year at Wickiup Dam

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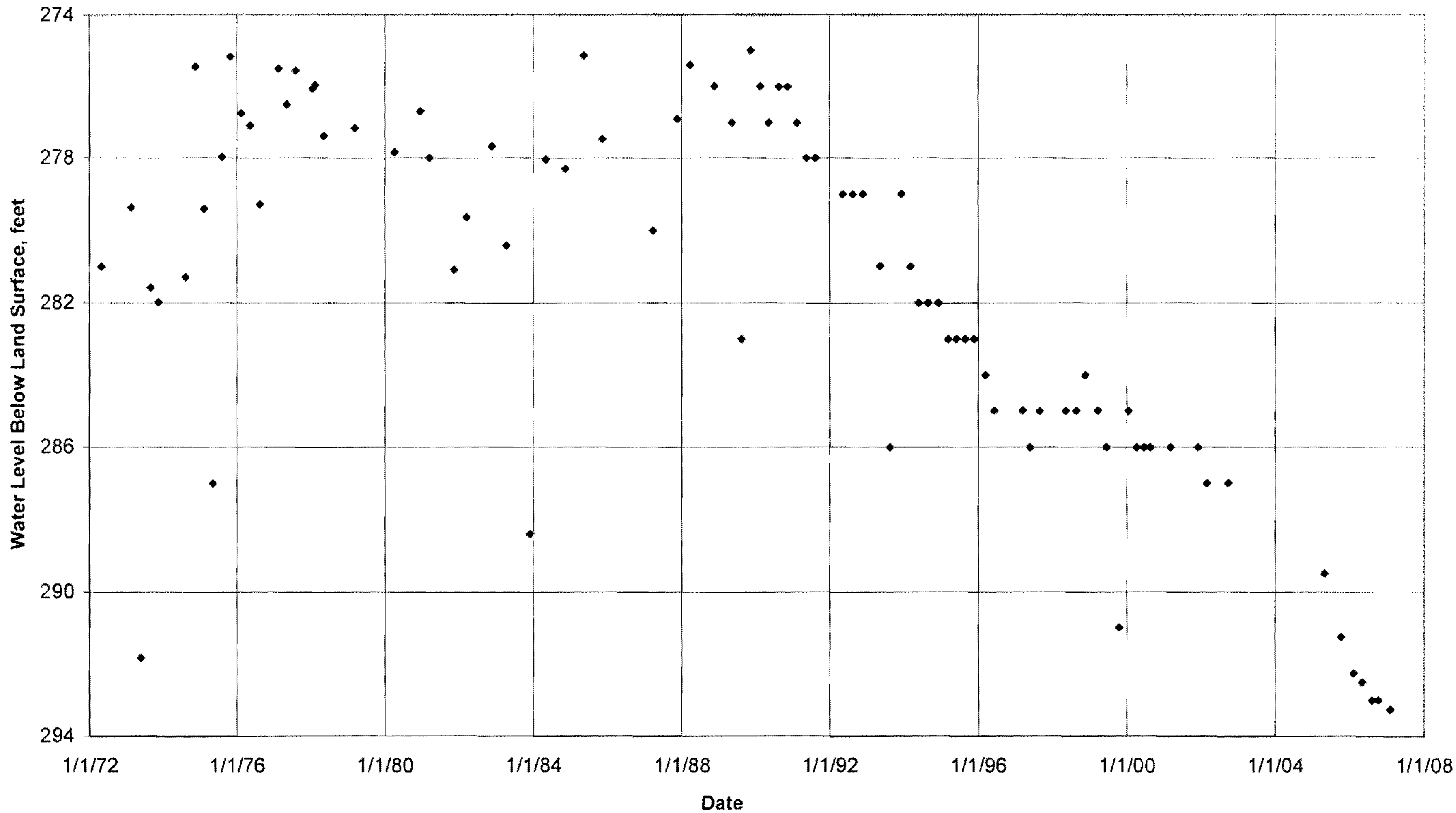

Figure 6-4.

Hydrograph for Upper Deschutes Basin Observation Well DESC 3903

Max Depth = 440 feet

Data from OWRD website: http://www.wrd.state.or.us/OWRD/GW/well_data.shtml

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D:\projects\Thornburgh\WaterLevelData\USGS_ObsWellData.xls;Fig6-4 DESC 3903

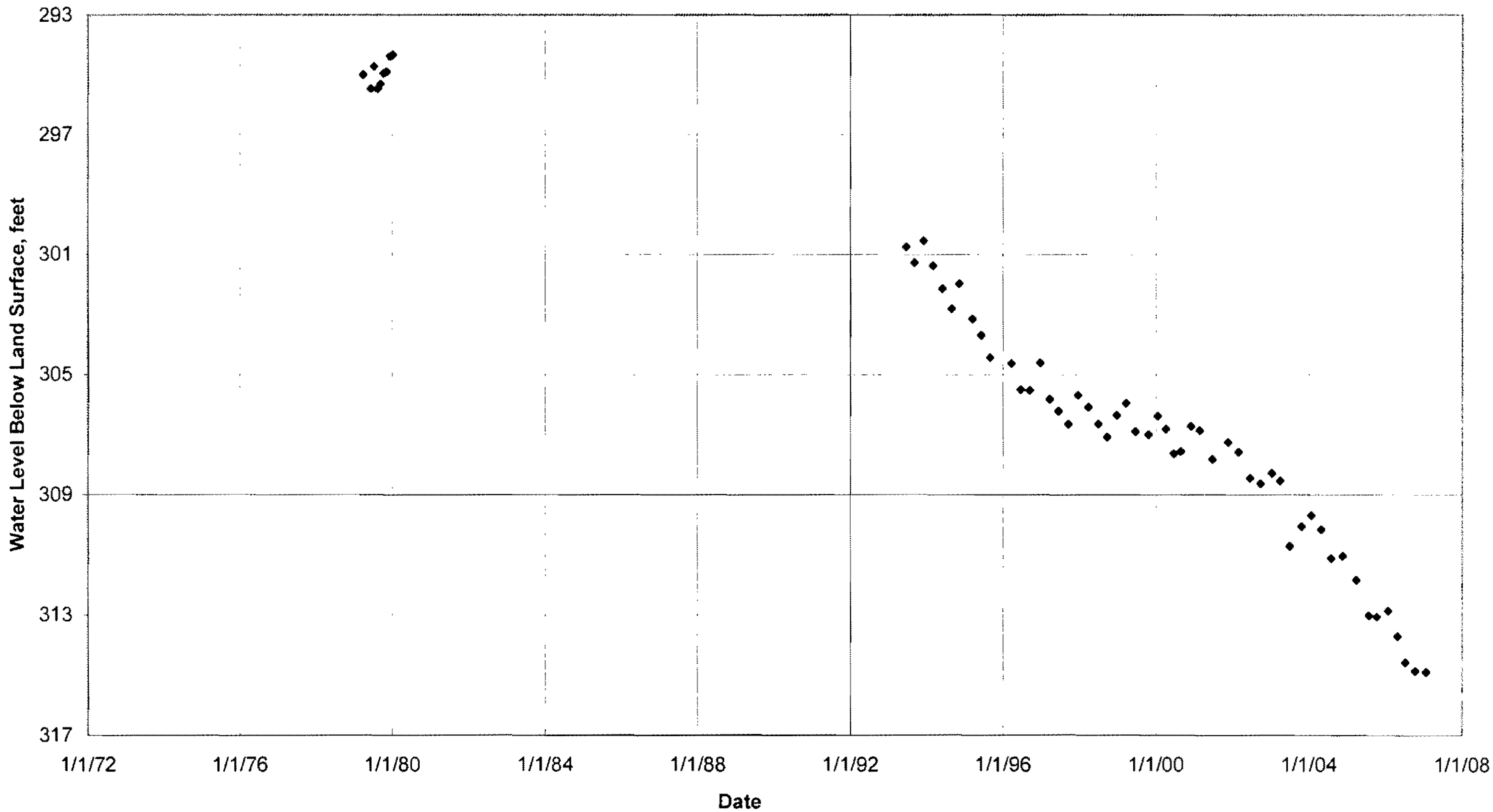

Figure 6-5.

Hydrograph for Upper Deschutes Basin Observation Well DESC 3949 (15S/13E-21ADB1)

Max Depth = 390 feet

Data from OWRD website: http://www.wrd.state.or.us/OWRD/GW/well_data.shtml

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D:\projects\Thornburgh\WaterLevelData\USGS_ObsWellData.xls; Fig 6-5 DESC 3949

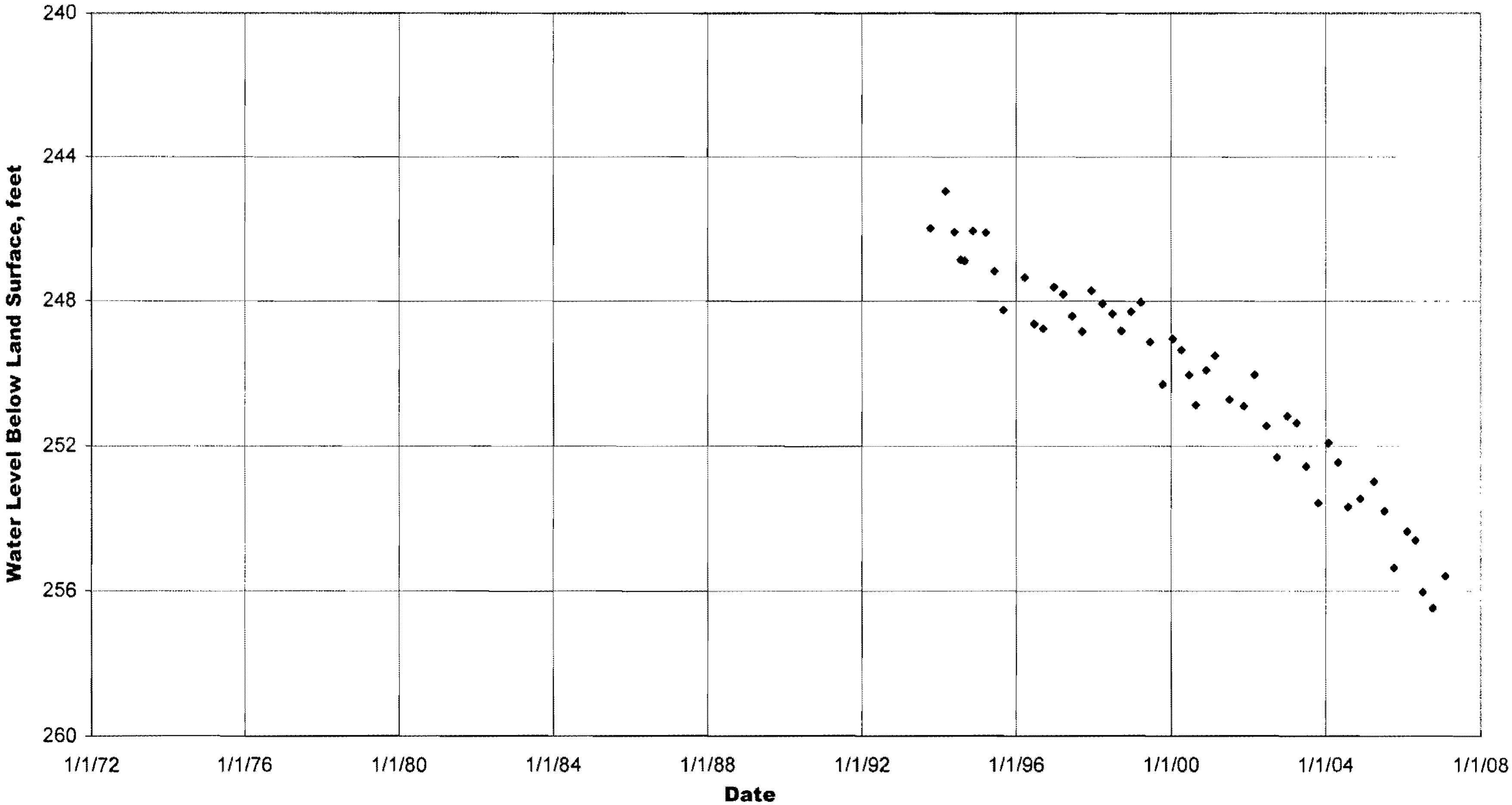

Figure 6-6.
Hydrograph for Upper Deschutes Basin Observation Well DESC 3581 (15S/12E-14CDD)
Max Depth = 303 feet
Data from OWRD website: http://www.wrd.state.or.us/OWRD/GW/well_data.shtml

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D:\projects\Thornburgh\WaterLevelData\USGS_ObsWellData.xls;Fig 6-6 DESC 3581

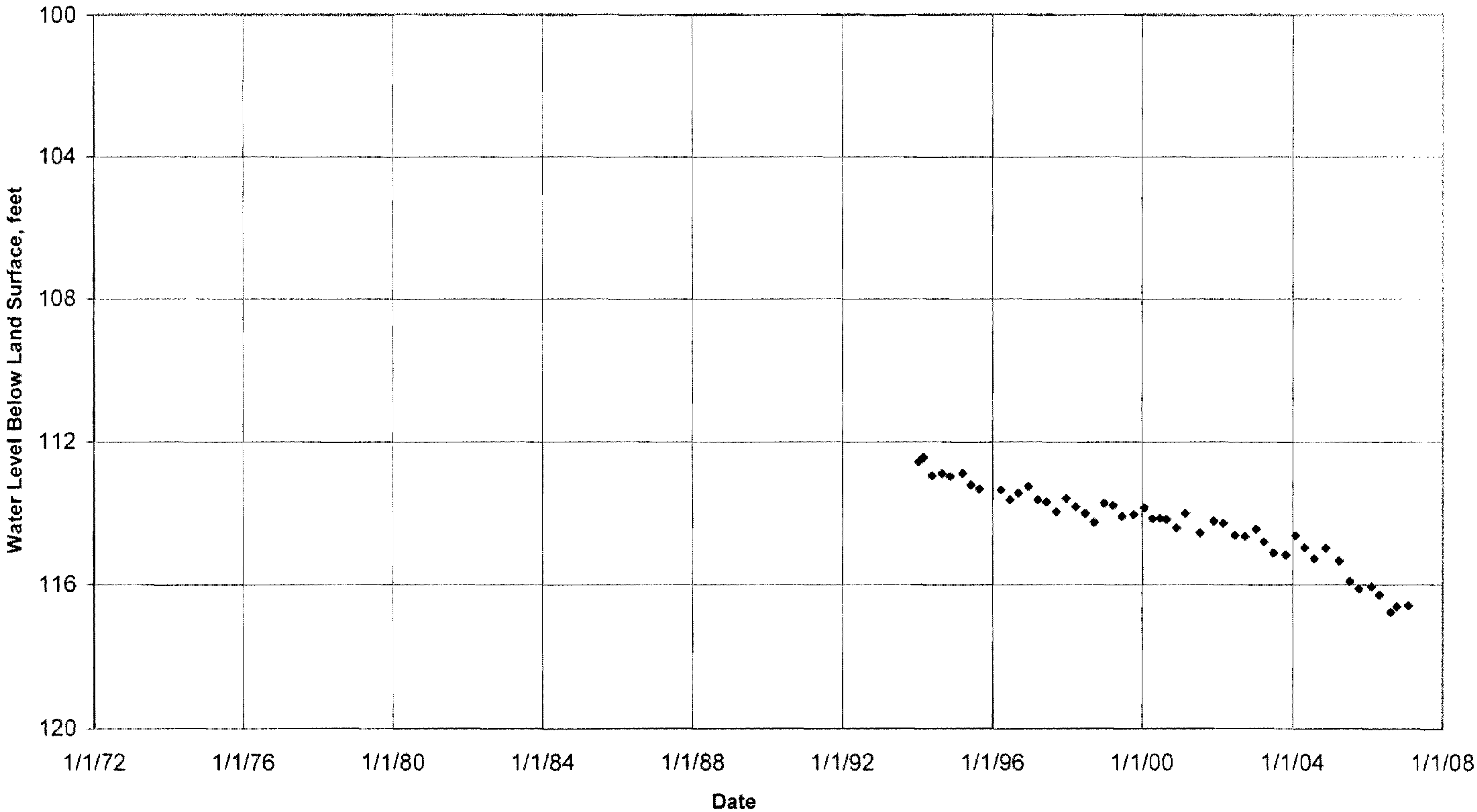

Figure 6-7.

Hydrograph for Upper Deschutes Basin Observation Well DESC 8626 (14S/12E-02CCC)

Maximum depth = 160 feet

Data from OWRD website: http://www.wrd.state.or.us/OWRD/GW/well_data.shtml

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D:\projects\Thornburgh\WaterLevelData\USGS_ObsWellData.xls,fig 6-7 DESC 8626

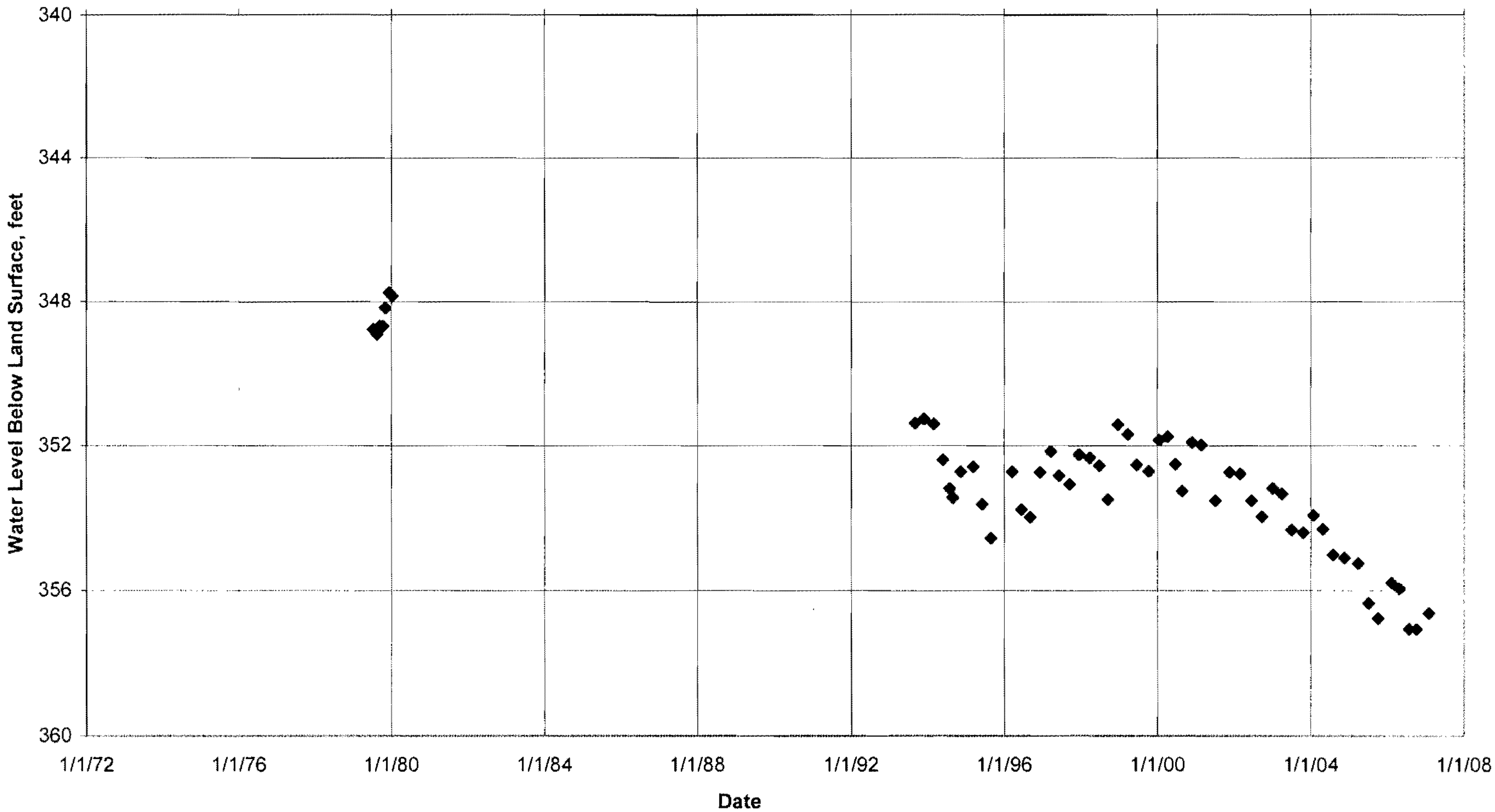

Figure 6-8.

Hydrograph for Upper Deschutes Basin Observation Well DESC 1957 (14S/11E-01DDD1)

Maximum depth = 410 feet

Data from OWRD website: http://www.wrd.state.or.us/OWRD/GW/well_data.shtml

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D:\projects\Thornburgh\WaterLevelData\USGS_ObsWellData.xls;fig 6-8 DESC 1957

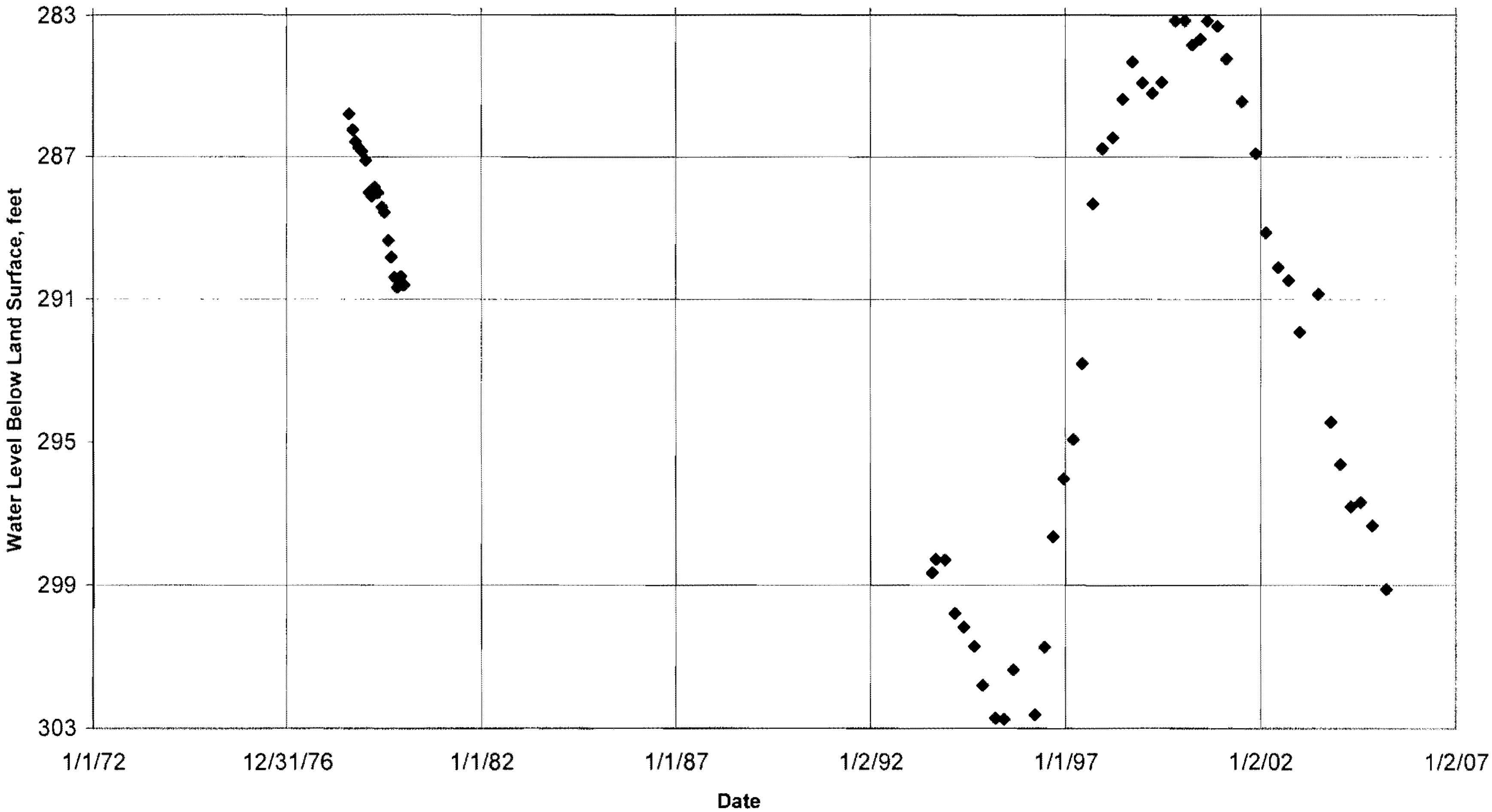

Figure 6-9.

Hydrograph for Upper Deschutes Basin Observation Well DESC 3193 (15S/10E-36AAD2)

Maximum depth = 365 feet

Data from OWRD website: http://www.wrd.state.or.us/OWRD/GW/well_data.shtml

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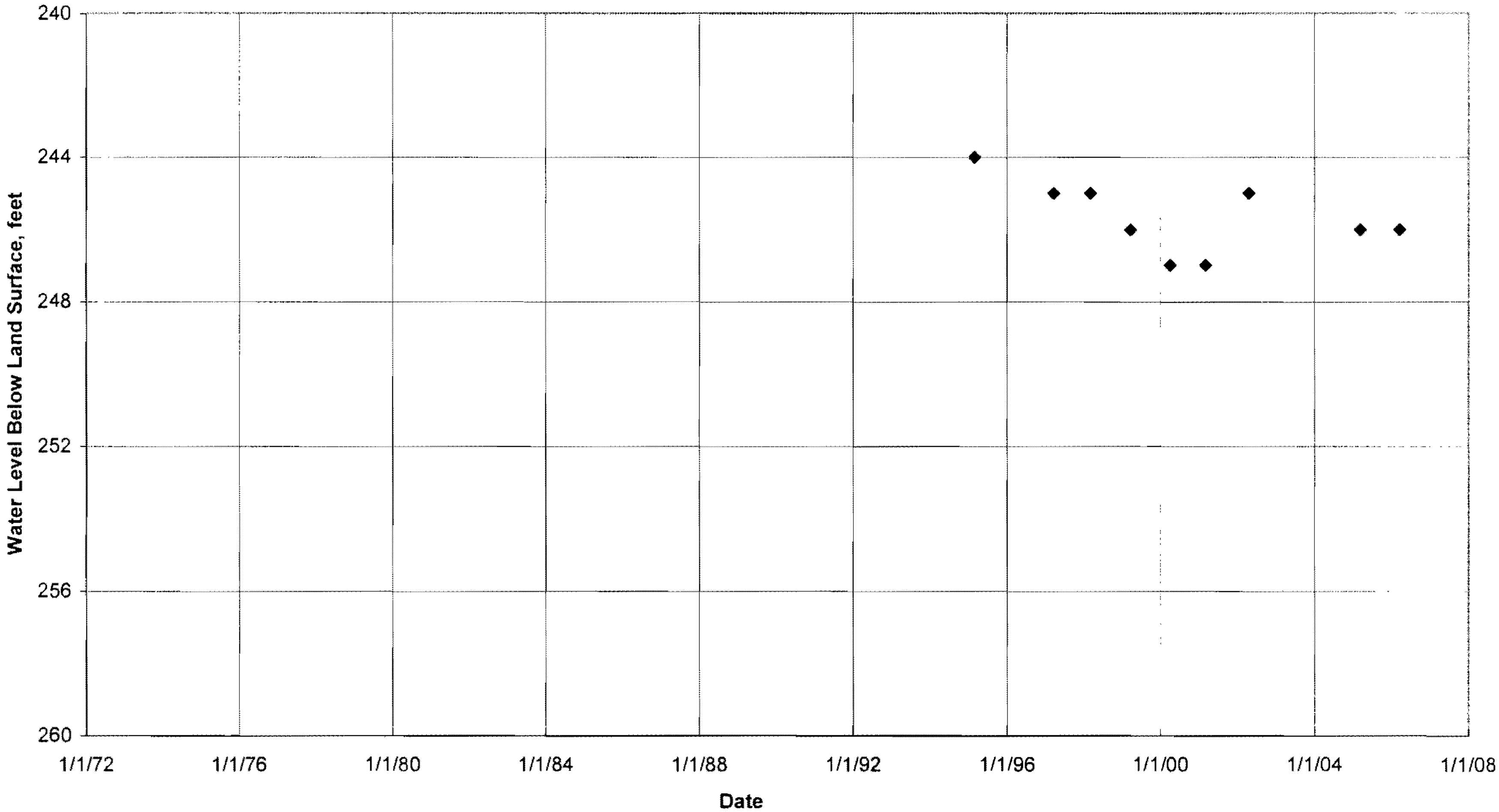

Figure 6-10.

Hydrograph for Upper Deschutes Basin Observation Well DESC 3614 (Eagle Crest Well #2)

Maximum Depth = 330 feet

Data from OWRD website: http://www.wrd.state.or.us/OWRD/GW/well_data.shtml

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D:\projects\Thornburgh\WaterLevelData\USGS_ObsWellData.xls;fig 6-10 DESC 3614

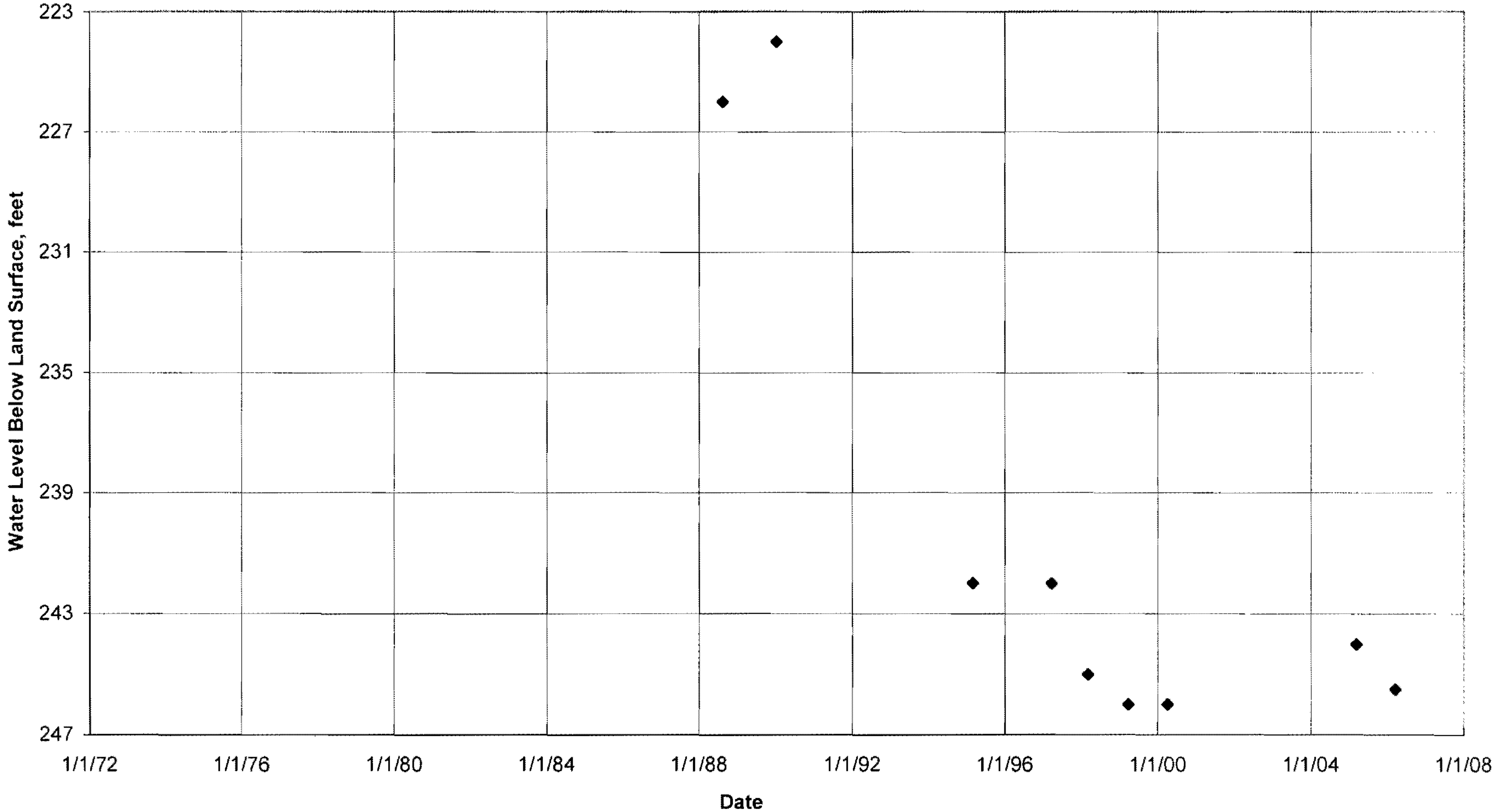

Figure 6-11.

Hydrograph for Upper Deschutes Basin Observation Well DESC 53714 (Eagle Crest #3)

Max Depth = 290 feet

Data from OWRD website:http://www.wrd.state.or.us/OWRD/GW/well_data.shtml

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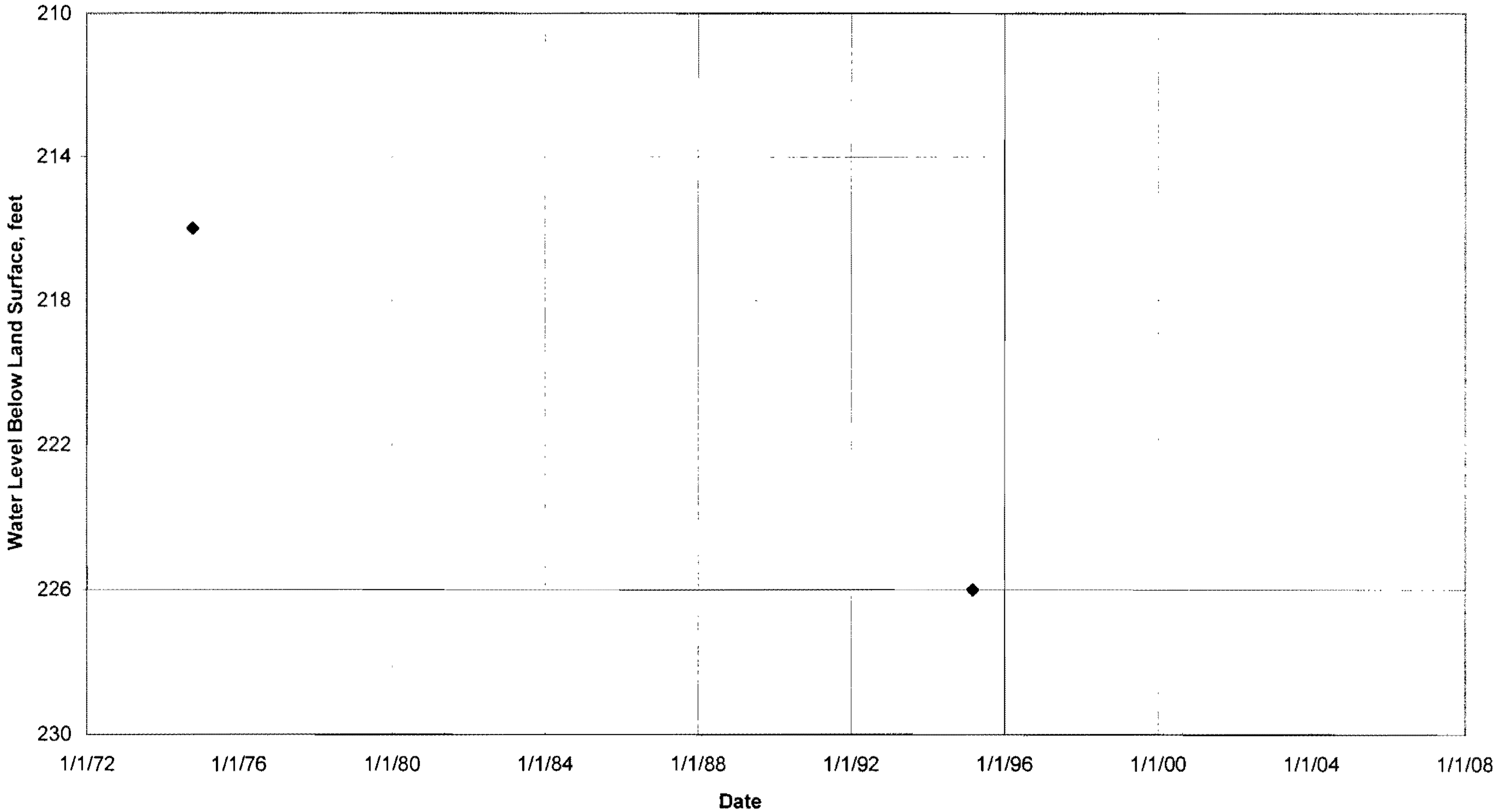

Figure 6-12.

Hydrograph for Upper Deschutes Basin Observation Well DESC 386 (Eagle Crest #1)

Maximum Depth = 268 feet

Data from OWRD website: http://www.wrd.state.or.us/OWRD/GW/well_data.shtml

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D:\projects\Thornburgh\WaterLevelData\USGS_ObsWellData.xls;fig 6-12 DESC 386

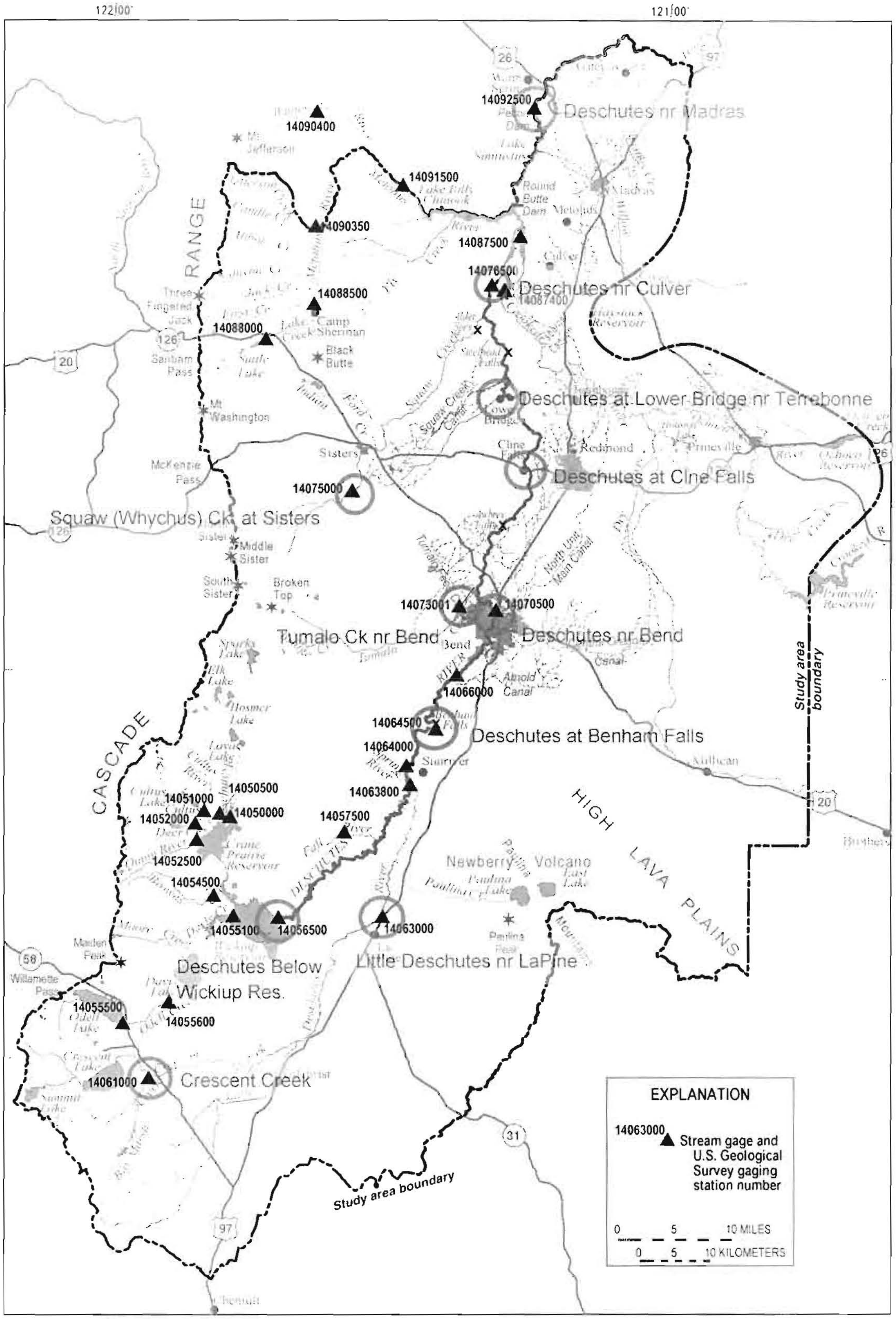

Figure 6-13.
Selected Stream-Gaging Stations in the Upper Deschutes Basin, Oregon (From Gannett and others, 2001)

Gaging station used in this report

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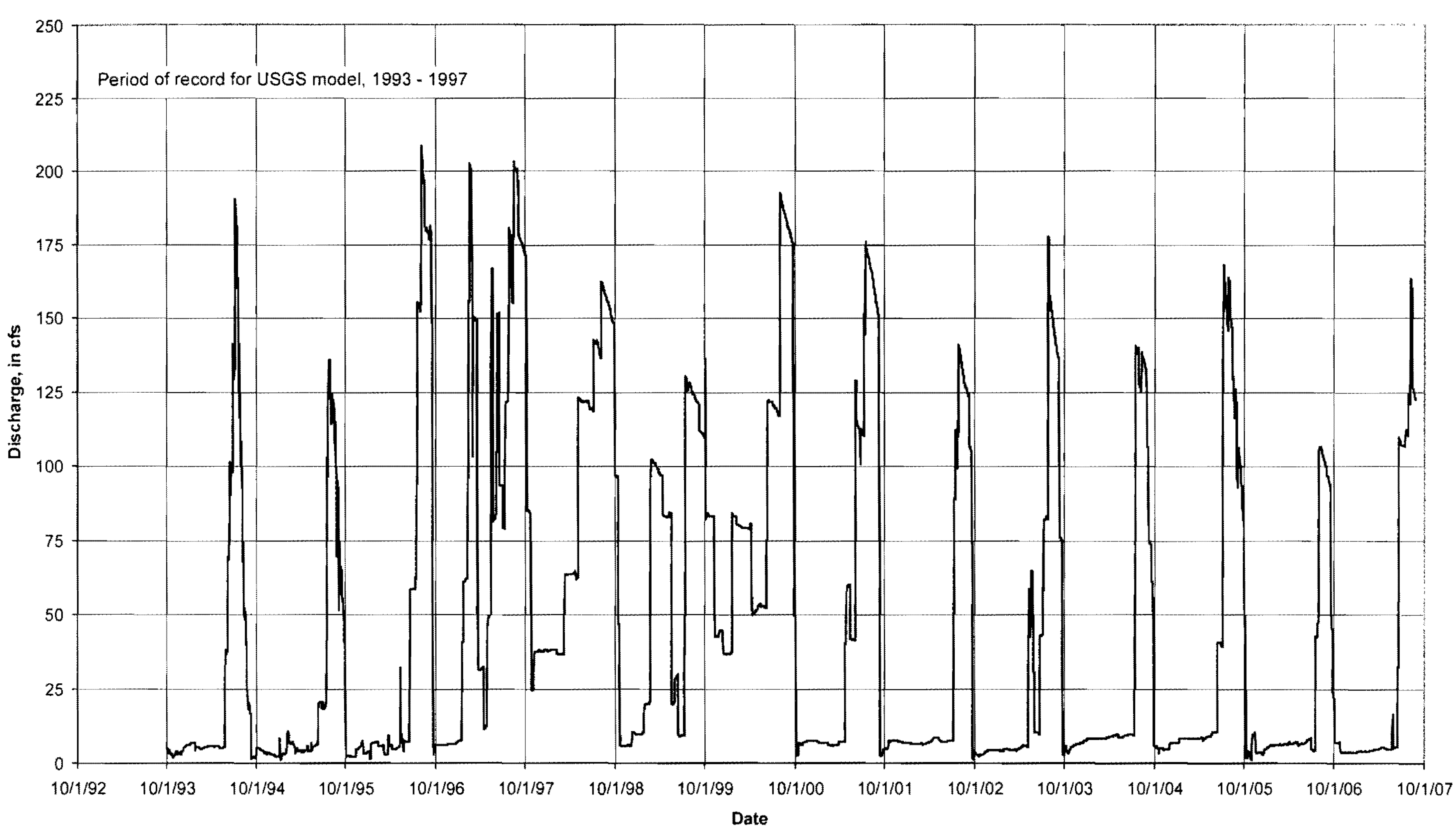

Figure 6-14. Streamflow Hydrograph for Gaging Station CREO - Crescent Creek at Crescent Lake, OR

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D:\projects\Thornburgh\Streamflow\DeschutesStreamData.xls;6-14 CREO-plot

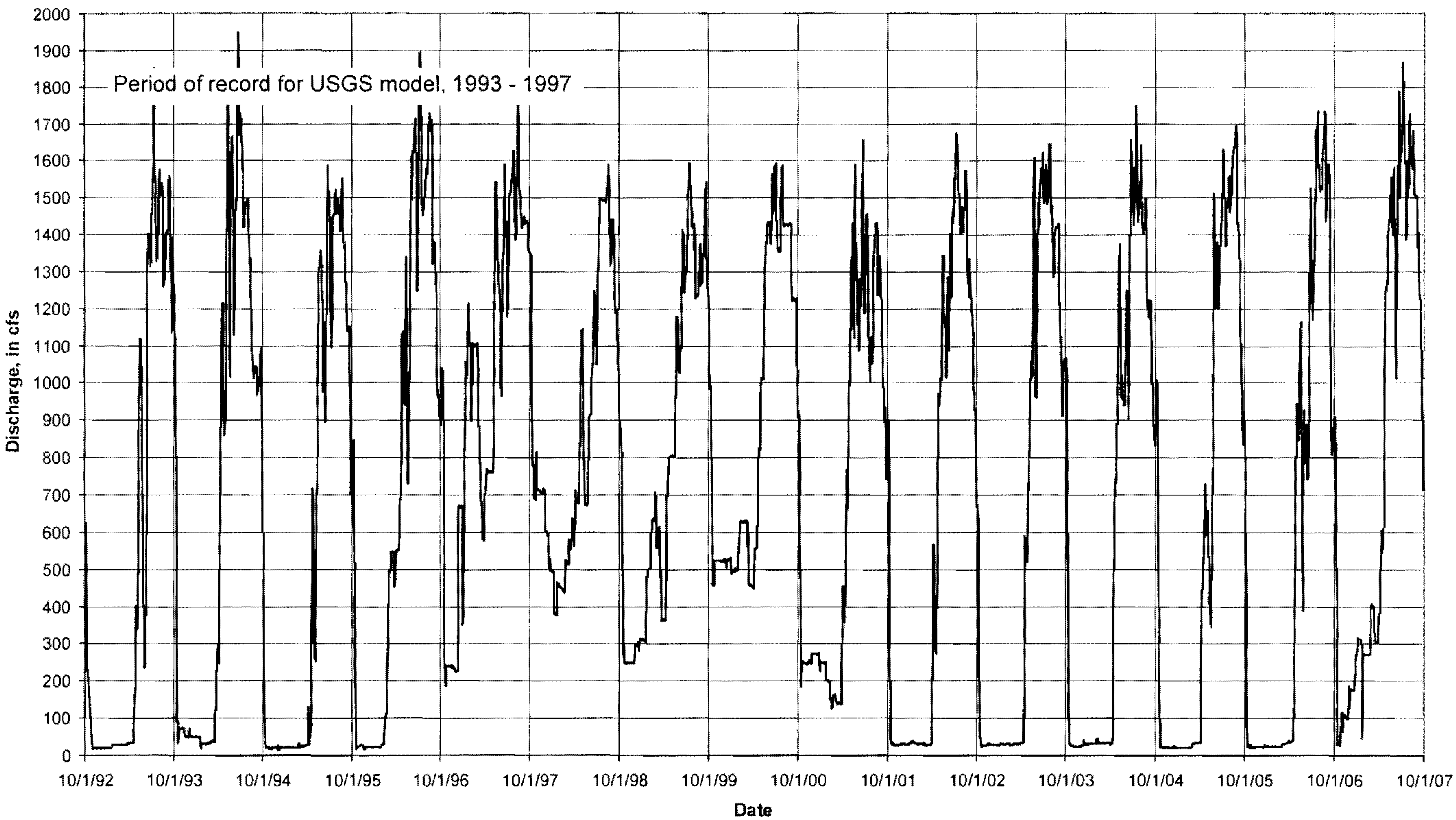

Figure 6-15. Streamflow Hydrograph for Gaging Station 14056500 - Deschutes River below Wickiup Res., OR

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Water Resources Impact Evaluation

D:\projects\Thornburgh\Streamflow\DeschutesStreamData.xls;6-15 Wico-plot

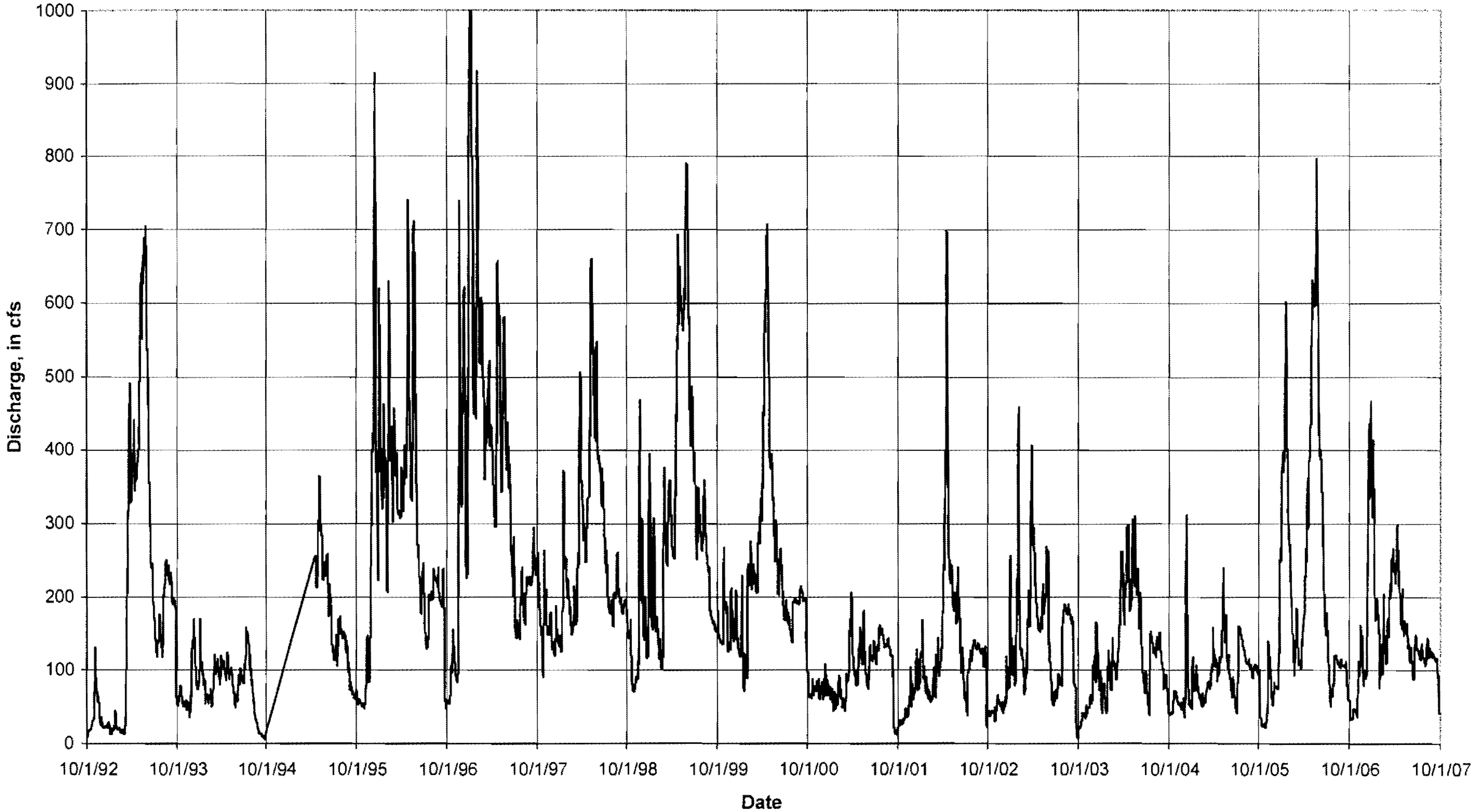

Figure 6-16. Streamflow Hydrograph for Gaging Station 14063000 - LAPO Little Deschutes River near LaPine, OR

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Water Resources Impact Evaluation

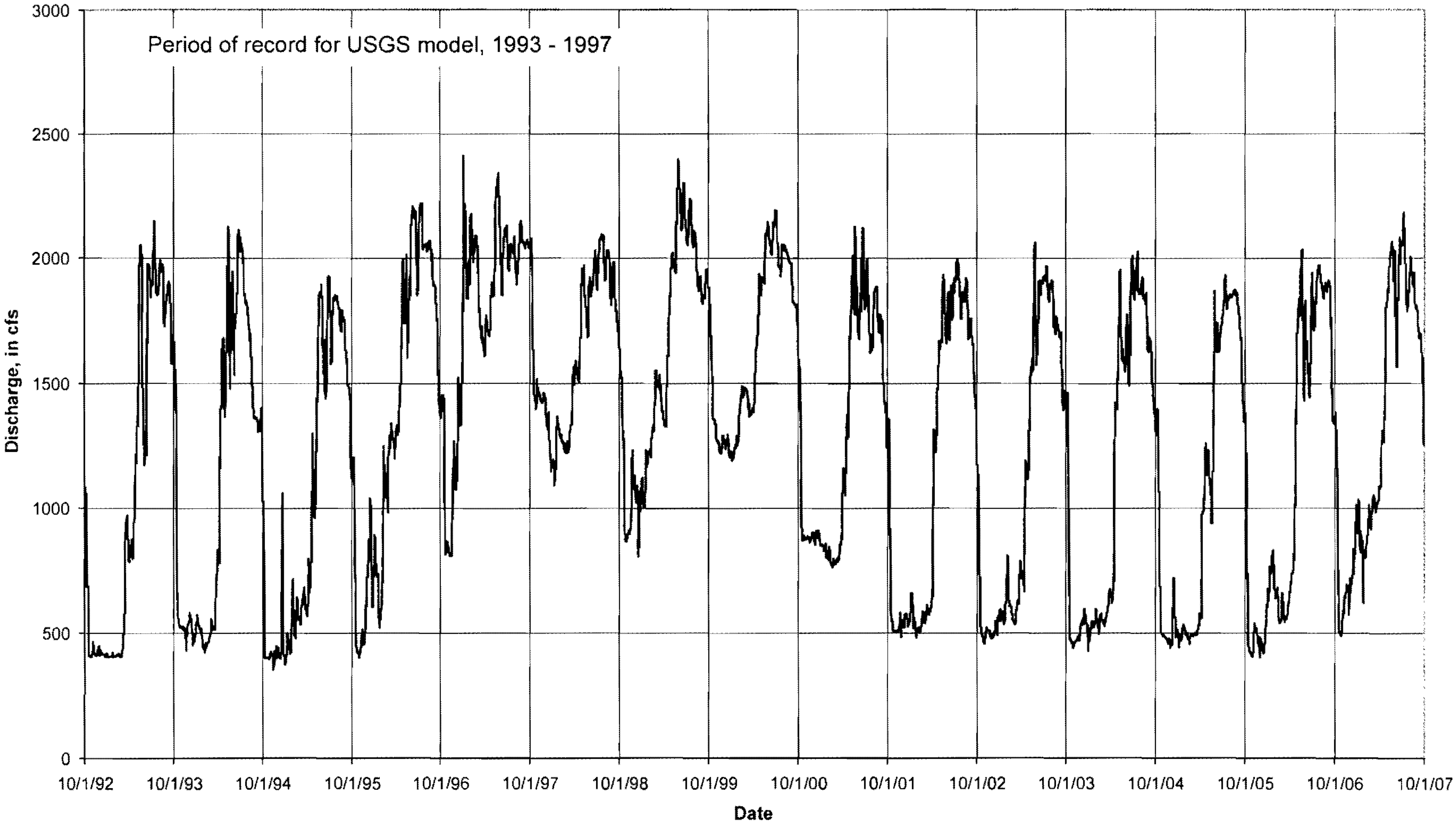

Figure 6-17. Streamflow Hydrograph for Gaging Station 14064500 BENO - Deschutes River at Benham Falls, OR

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Water Resources Impact Evaluation

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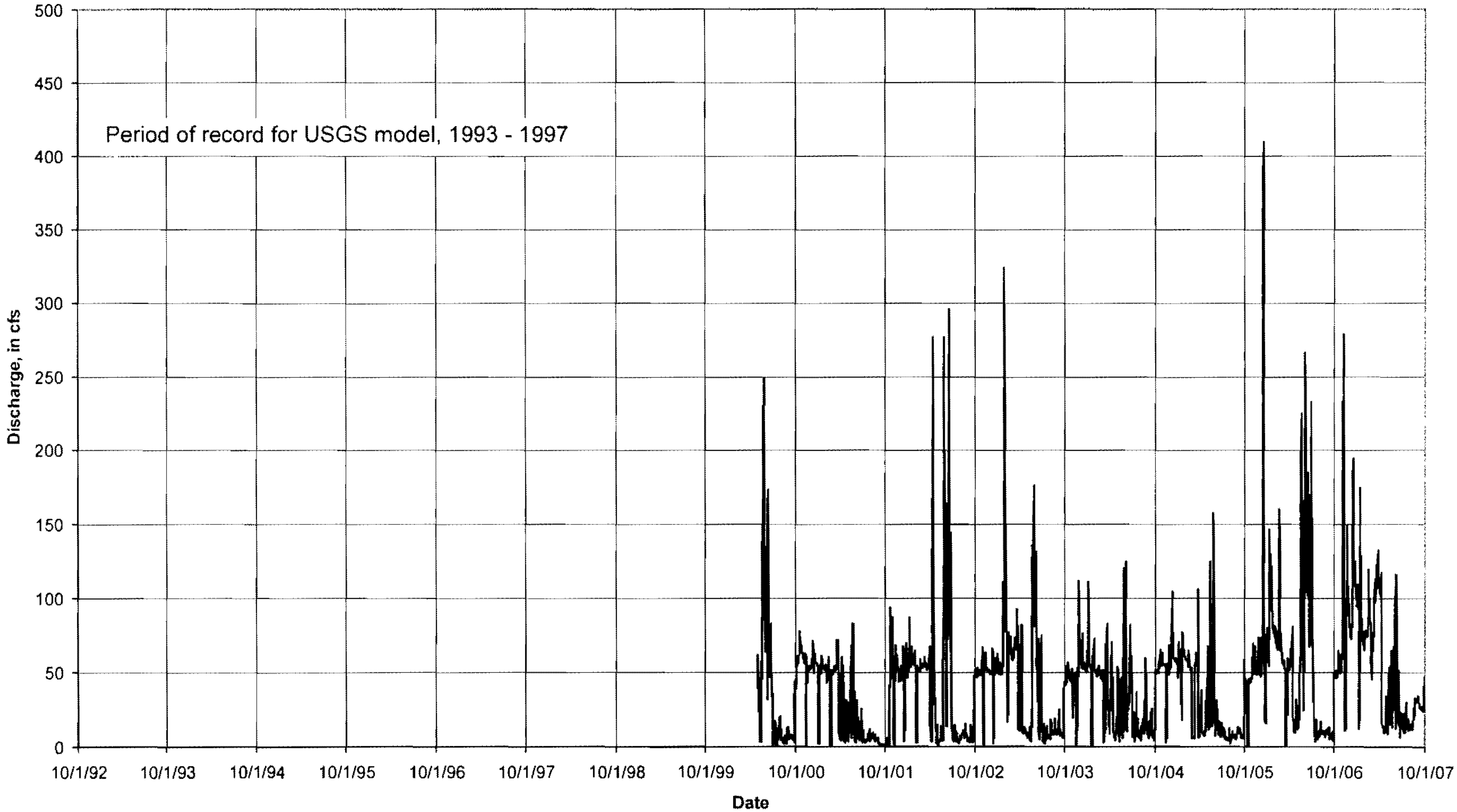

Figure 6-18. Streamflow Hydrograph for Gaging Station 14073001 TUMO - Tumalo Creek nr Bend, OR

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Consulting in Hydrogeology

Case Study: Thornburgh Resort
Water Resources Impact Evaluation

D:\projects\Thornburgh\Streamflow\DeschutesStreamData.xls;6-18 TUMO-plot

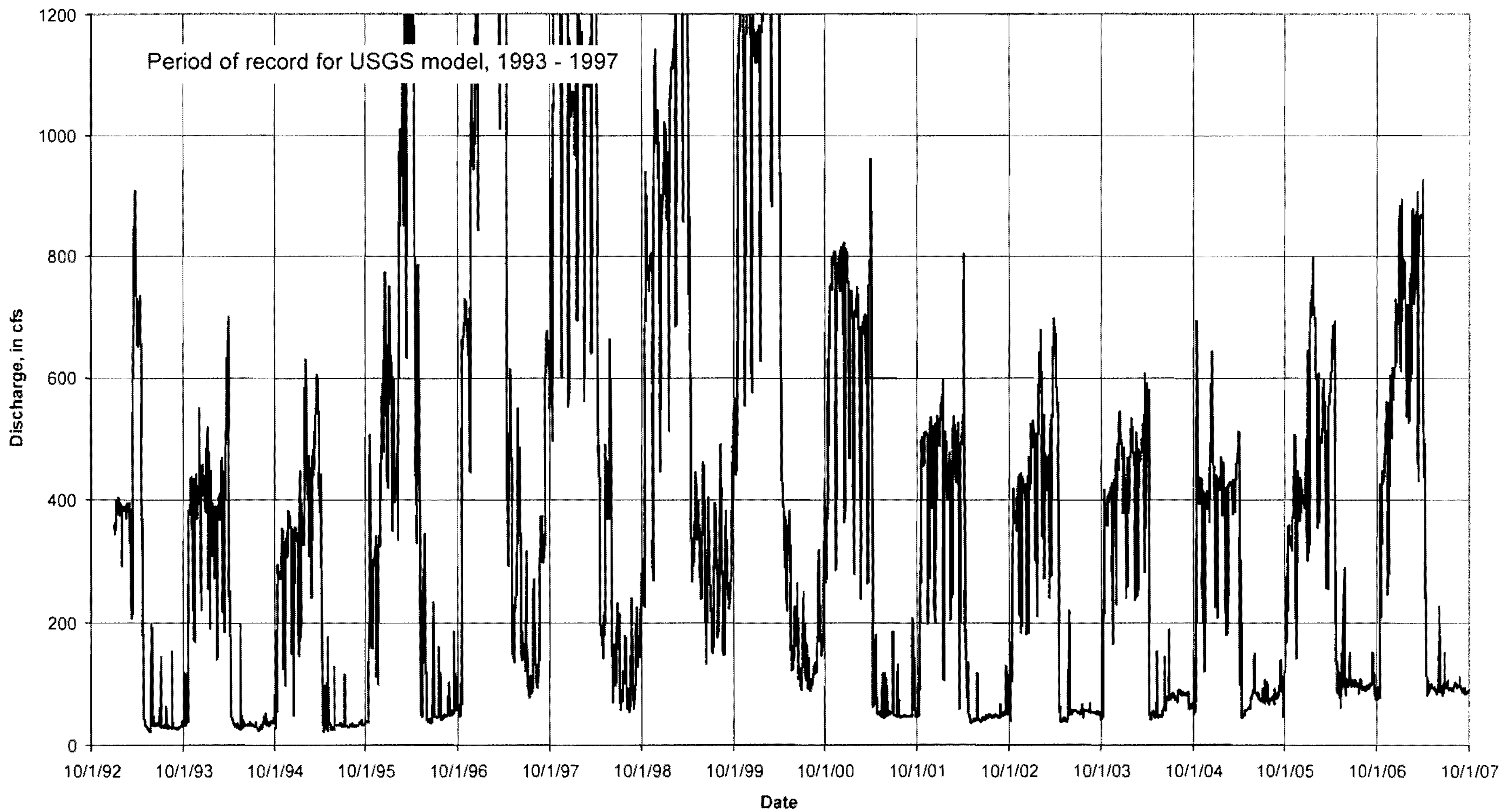

Figure 6-19. Streamflow Hydrograph for Gaging Station 14070500 Deschutes Nr. Bend

NORTHWEST Land & Water, INC.
Consulting in Hydrogeology

Case Study: Thornburgh Resort
Water Resources Impact Evaluation

D:\projects\Thornburgh\Streamflow\DeschutesStreamData.xls;6-19 Plot-14070500 Bend

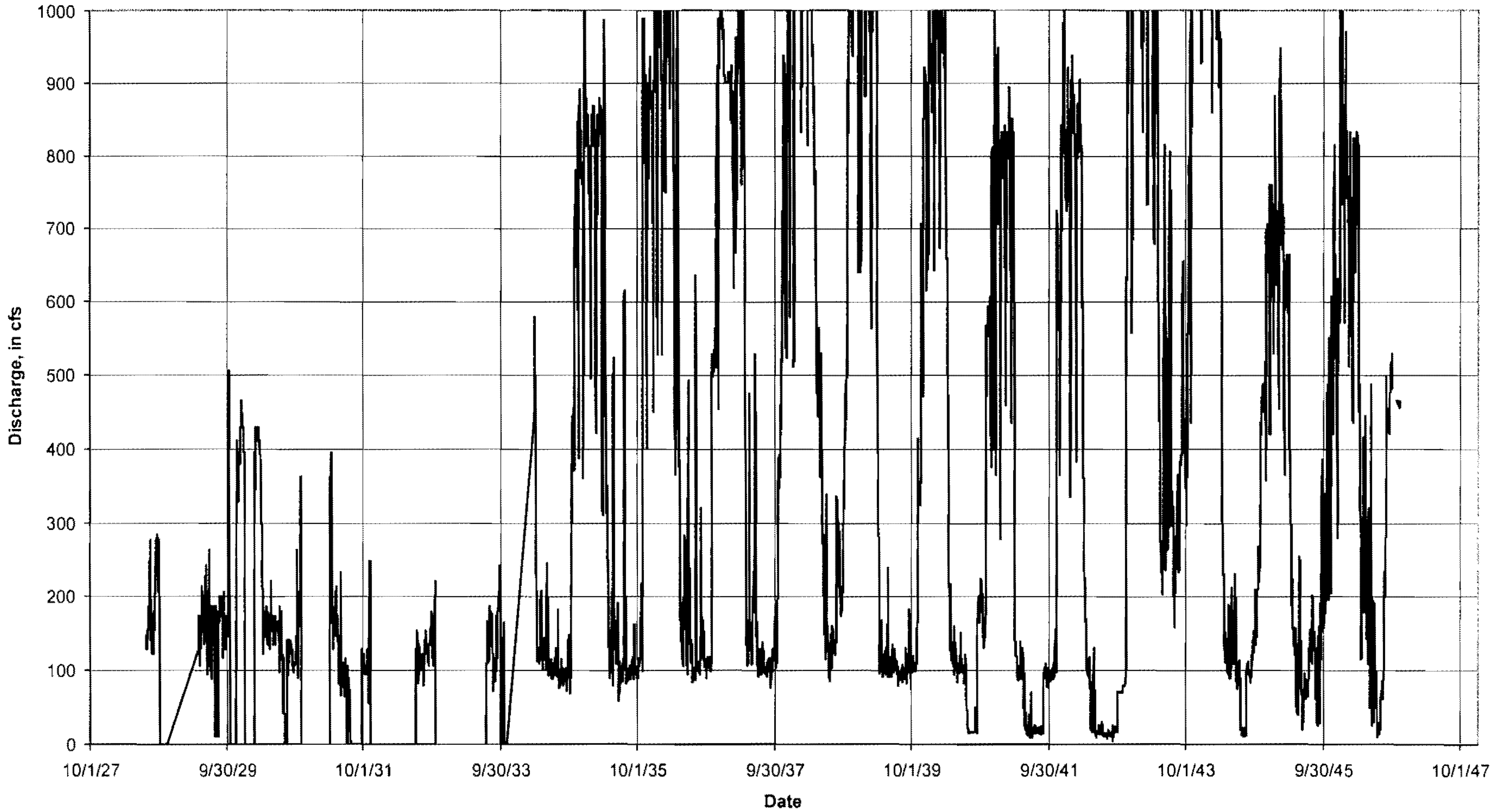

Figure 6-20. Streamflow Hydrograph for Gaging Station 14074500 Deschutes at Cline Falls Nr Redmond

NORTHWEST Land & Water, INC.
Consulting in Hydrogeology

Case Study: Thornburgh Resort
Water Resources Impact Evaluation

D:\projects\Thornburgh\Streamflow\DeschutesStreamData.xls;6-20 Plot-14074500 cline

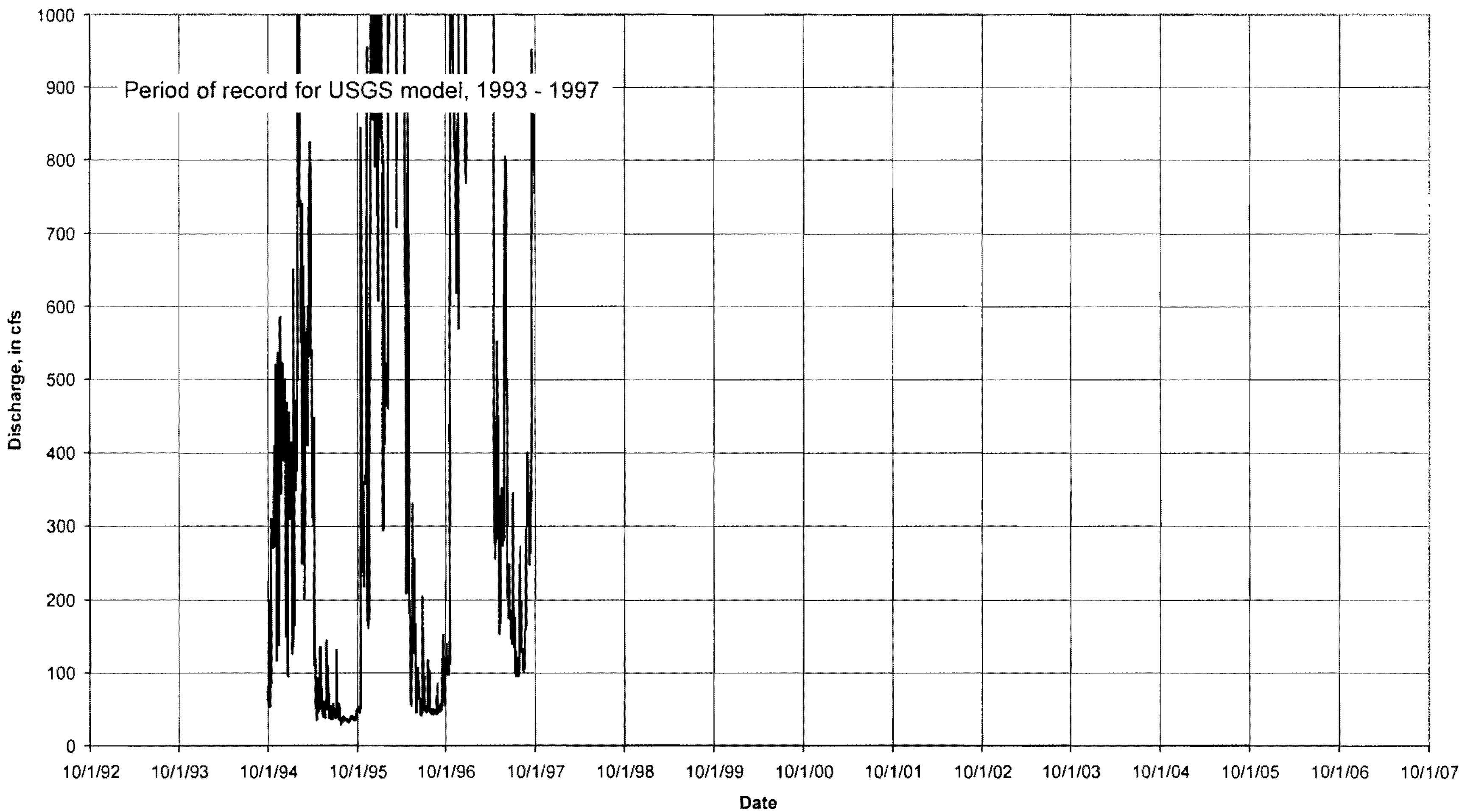

Figure 21. Streamflow Hydrograph for Gaging Station 14074630 Deschutes at Lower Bridge near Terrebonne

NORTHWEST Land & Water, INC.
Consulting in Hydrogeology

Case Study: Thornburgh Resort
Water Resources Impact Evaluation

D:\projects\Thornburgh\Streamflow\DeschutesStreamData.xls;6-21 Plot-14074630 Terrbon

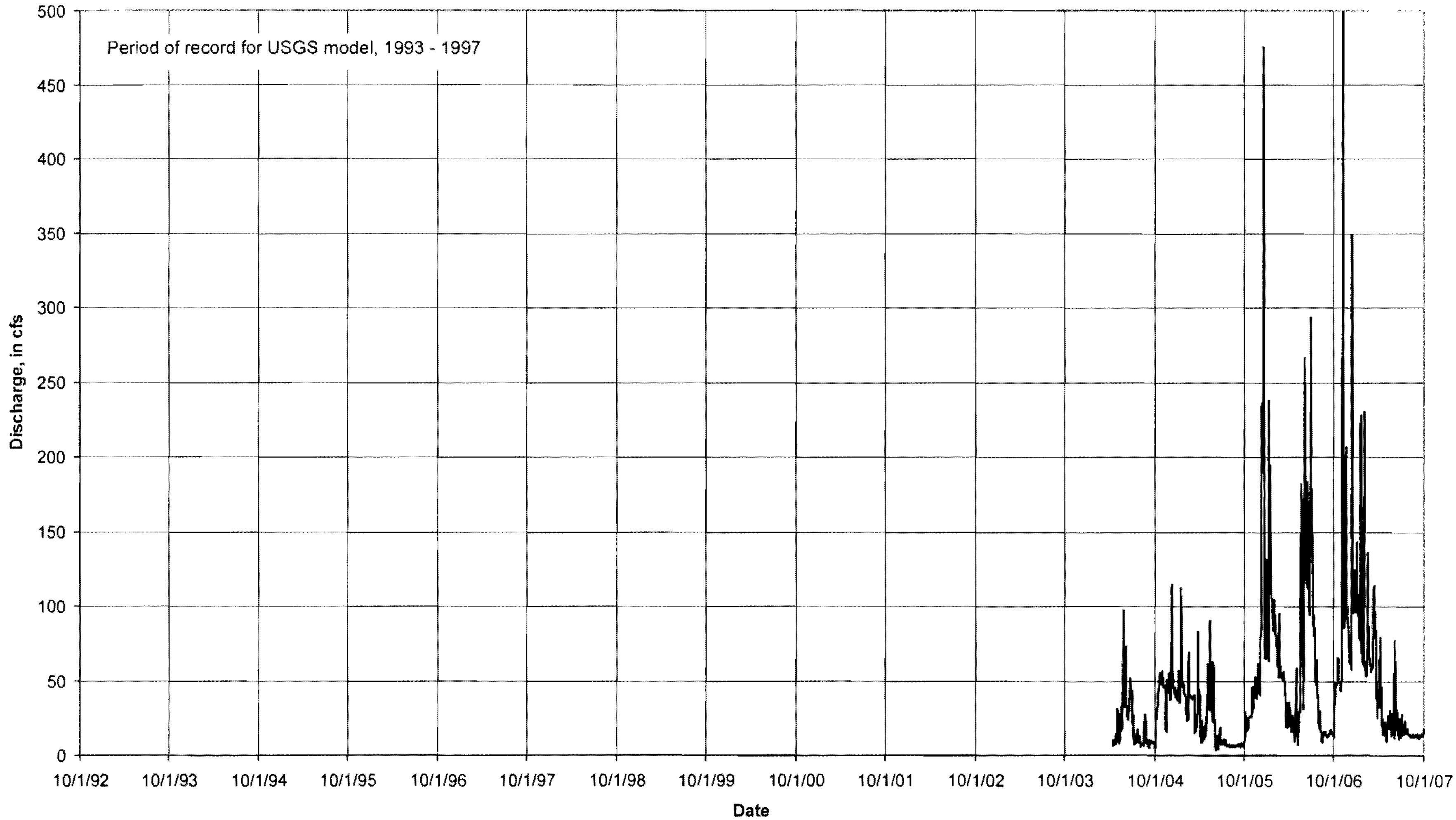

Figure 6-22. Streamflow Hydrograph for Gaging Station 14075000 SQSO - Whychus (Squaw) Creek at Sisters, OR

NORTHWEST Land & Water, INC.
Consulting in Hydrogeology

Case Study: Thornburgh Resort
Water Resources Impact Evaluation

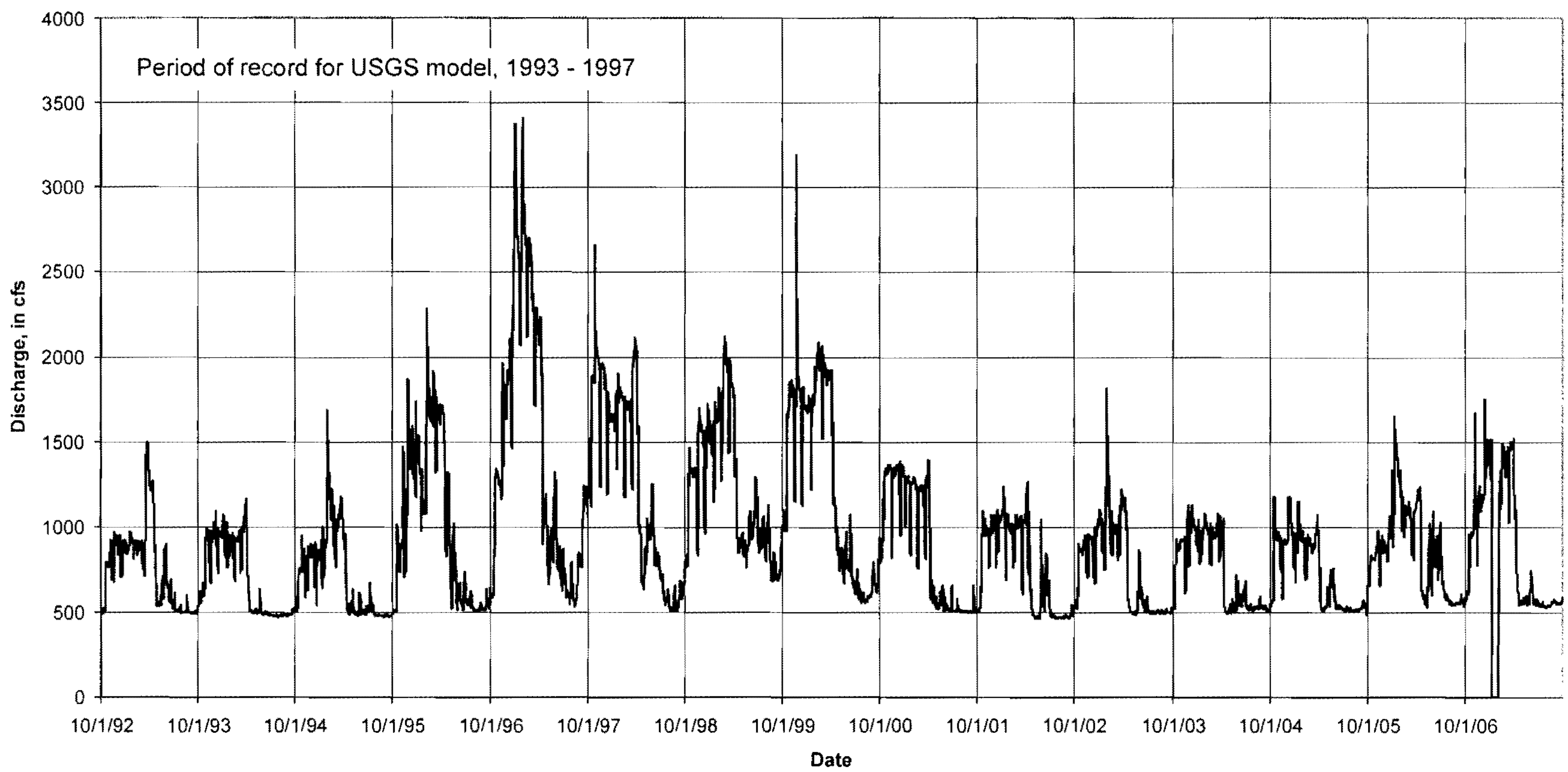

Figure 6-23. Streamflow Hydrograph for Gaging Station USGS 14076500 Deschutes River near Culver, Oregon

NORTHWEST Land & Water, INC.
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Case Study: Thornburgh Resort
Water Resources Impact Evaluation

D:\projects\Thornburgh\Streamflow\DeschutesStreamData.xls;6-23 Plot-14076500 Cul

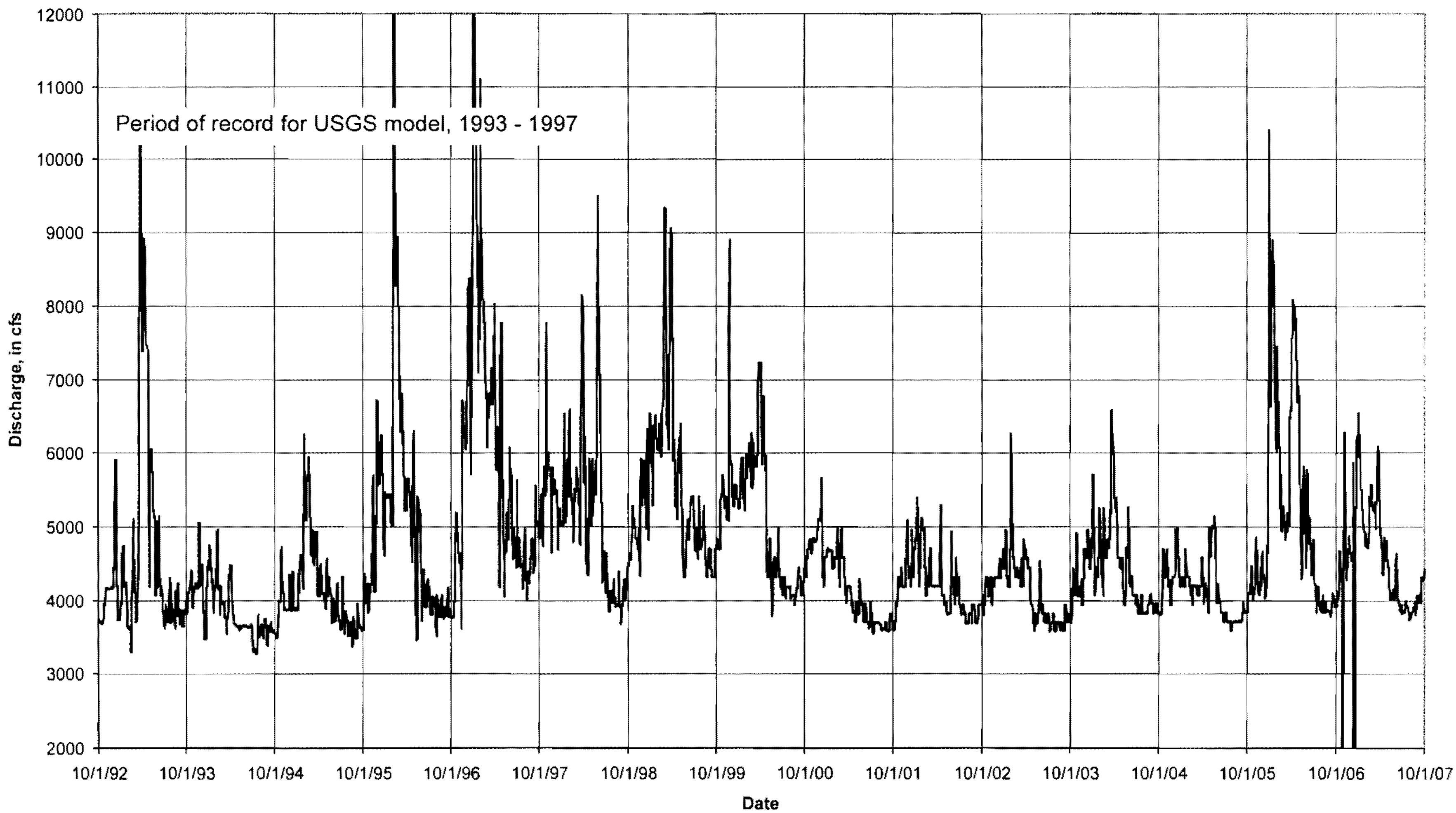

Figure 6-24. Streamflow Hydrograph for Gaging Station USGS 14092500 Deschutes River near Madras, OR

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Water Resources Impact Evaluation

D:\projects\Thornburgh\Streamflow\DeschutesStreamData.xls;6-24 Plot-14092500 madras

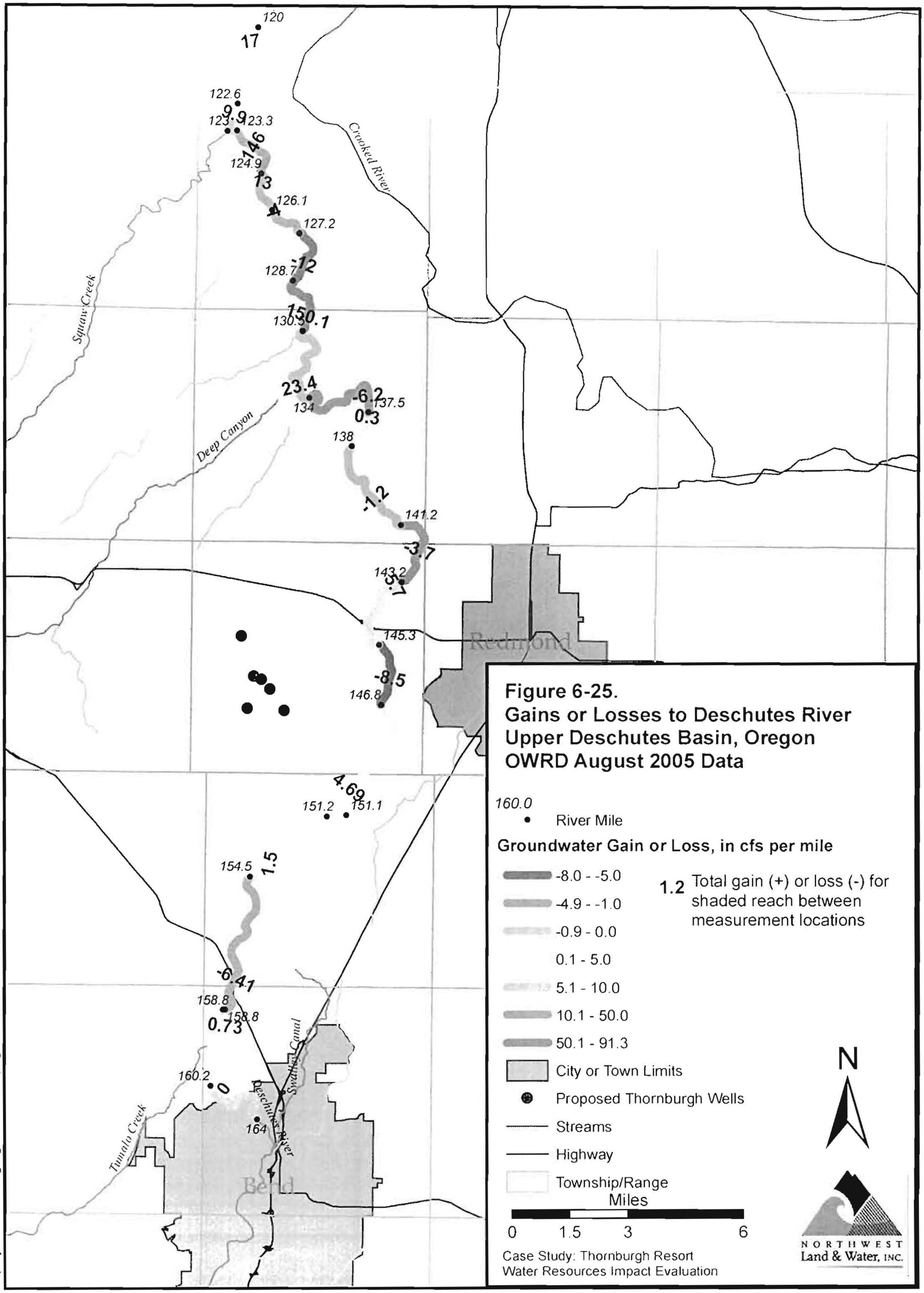

Figure 6-25.
Gains or Losses to Deschutes River
Upper Deschutes Basin, Oregon
OWRD August 2005 Data

d:\projects\thornburgh\gis\mxds\SeepageData.mxd

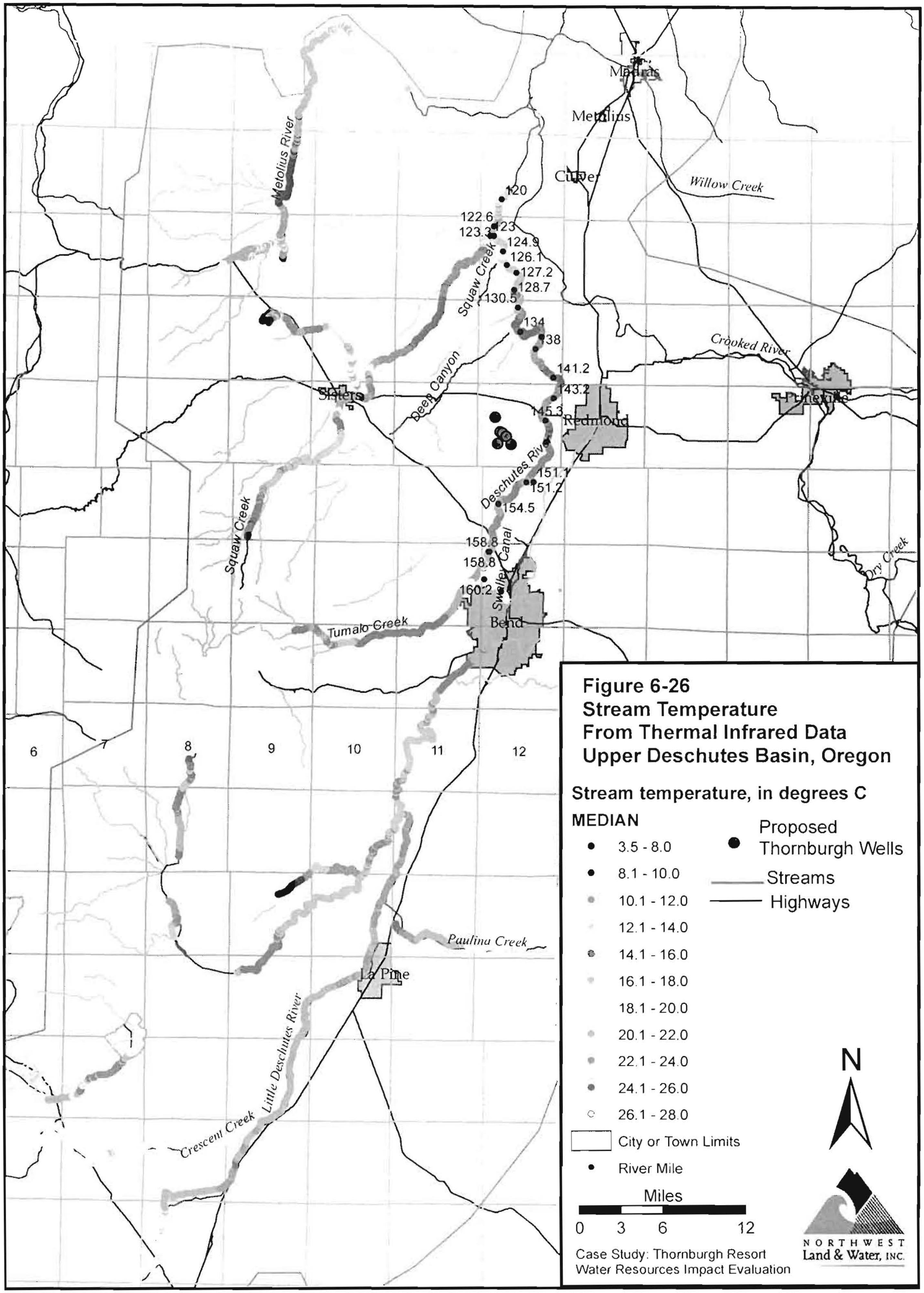
Figure 6-26
Stream Temperature
From Thermal Infrared Data
Upper Deschutes Basin, Oregon
Stream temperature, in degrees C
MEDIAN
3.5 - 8.0
8.1 - 10.0
10.1 - 12.0
12.1 - 14.0
14.1 - 16.0
16.1 - 18.0
18.1 - 20.0
20.1 - 22.0
22.1 - 24.0
24.1 - 26.0
26.1 - 28.0
City or Town Limits
River Mile
Proposed Thornburgh Wells
Streams
Highways
Miles
0 3 6 12
N
NORTHWEST Land & Water, INC.
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Madras
Metolius
Culver
Willow Creek
Metolius River
Crooked River
Prineville
Redmond
Sisters
Deep Canyon
Squaw Creek
Deschutes River
Swalley Canal
Tumalo Creek
Bend
Dry Creek
Paulina Creek
La Pine
Little Deschutes River
Crescent Creek
120
122.6
123
123.3
124.9
126.1
127.2
128.7
130.5
134
138
141.2
143.2
145.3
151.1
151.2
154.5
158.8
158.8
160.2
6
7
8
9
10
11
12

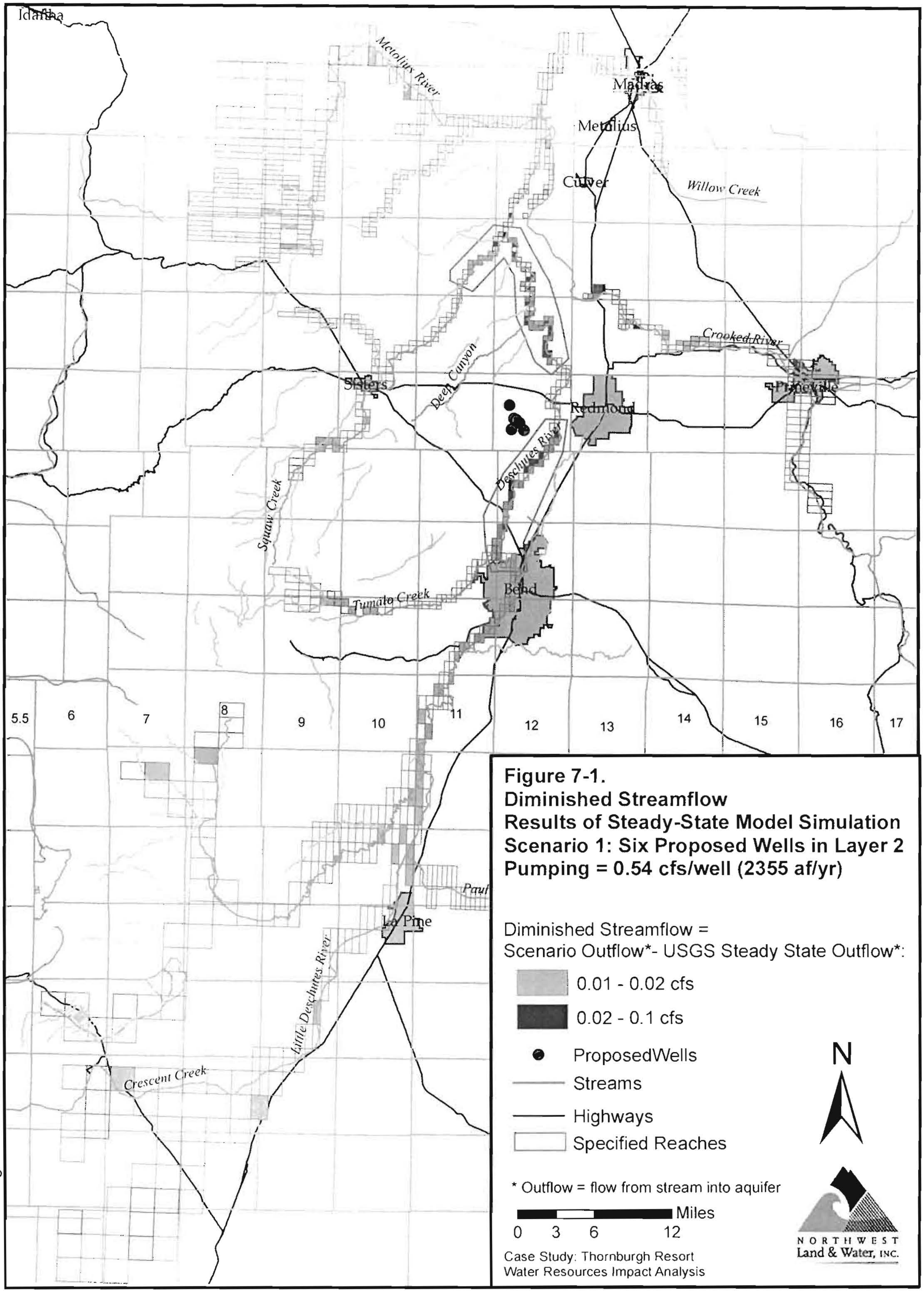


Figure 7-1.
Diminished Streamflow
Results of Steady-State Model Simulation
Scenario 1: Six Proposed Wells in Layer 2
Pumping = 0.54 cfs/well (2355 af/yr)

Scenario1Qavg-newsolver.mxd

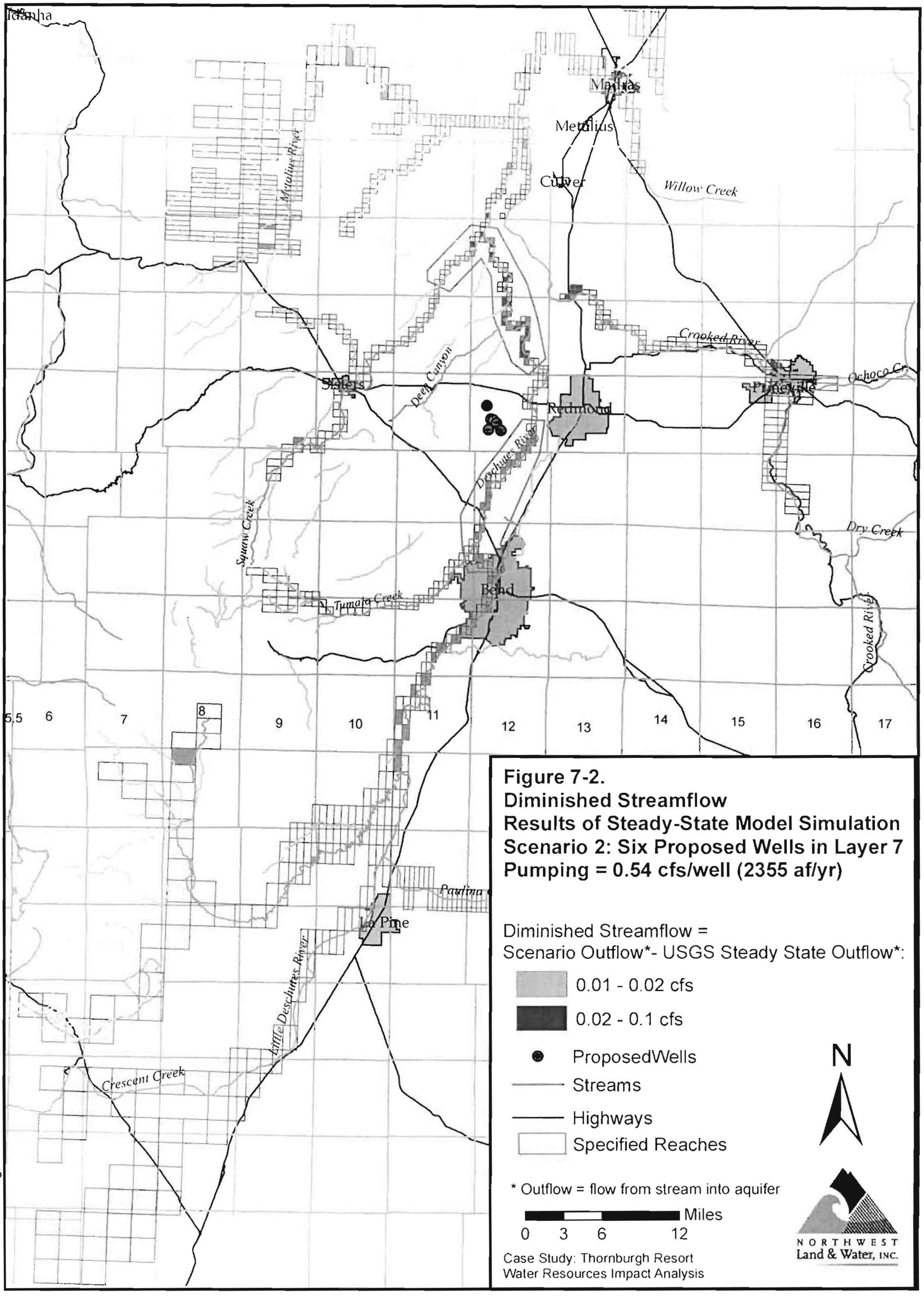


Figure 7-2.
Diminished Streamflow
Results of Steady-State Model Simulation
Scenario 2: Six Proposed Wells in Layer 7
Pumping = 0.54 cfs/well (2355 af/yr)

Scenario2Qavg-newsolver.mxd

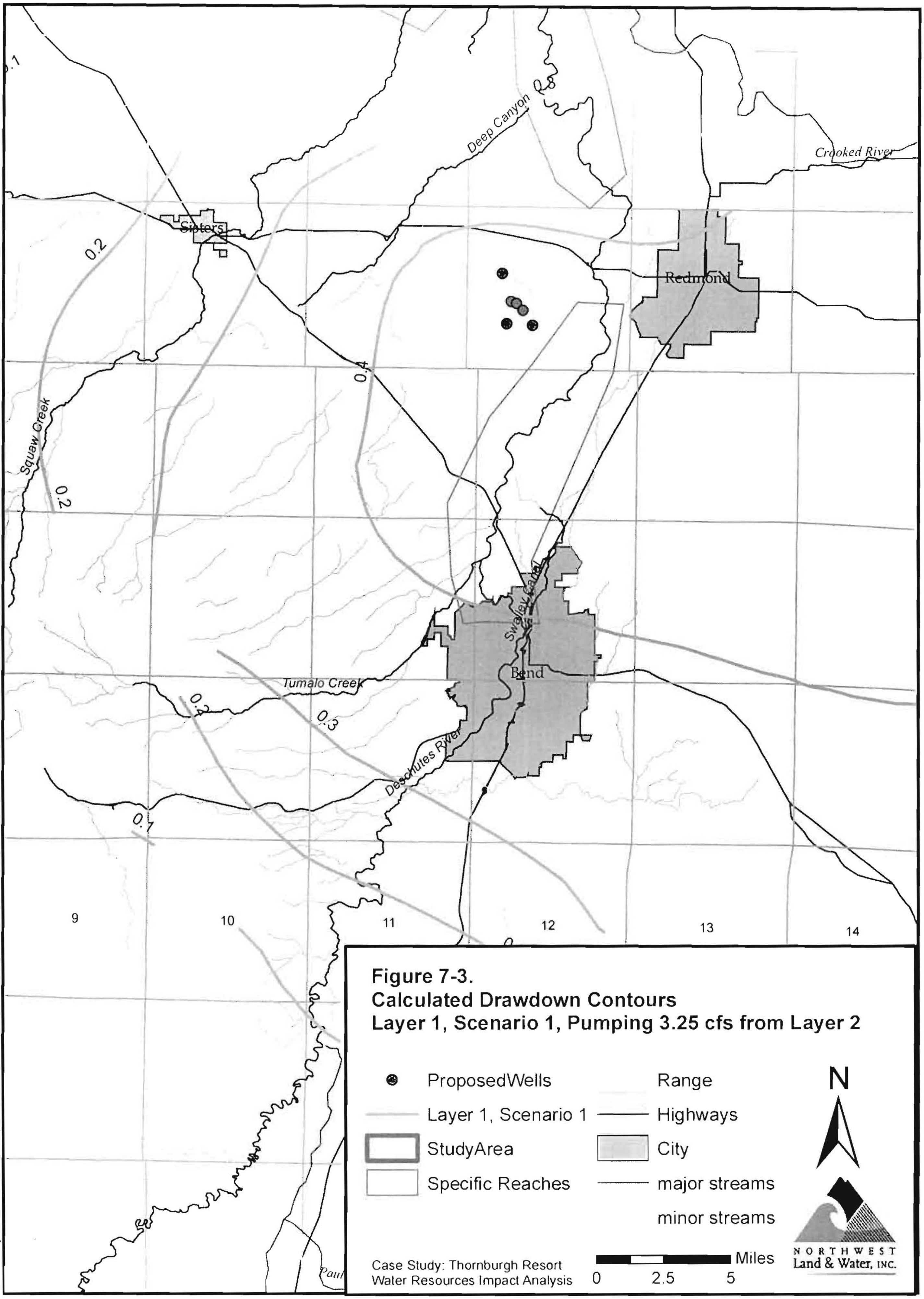


Figure 7-3.
Calculated Drawdown Contours
Layer 1, Scenario 1, Pumping 3.25 cfs from Layer 2

D:\Projects\Thornburgh\GIS\MXDs\Contours_L1Scen1.mxd

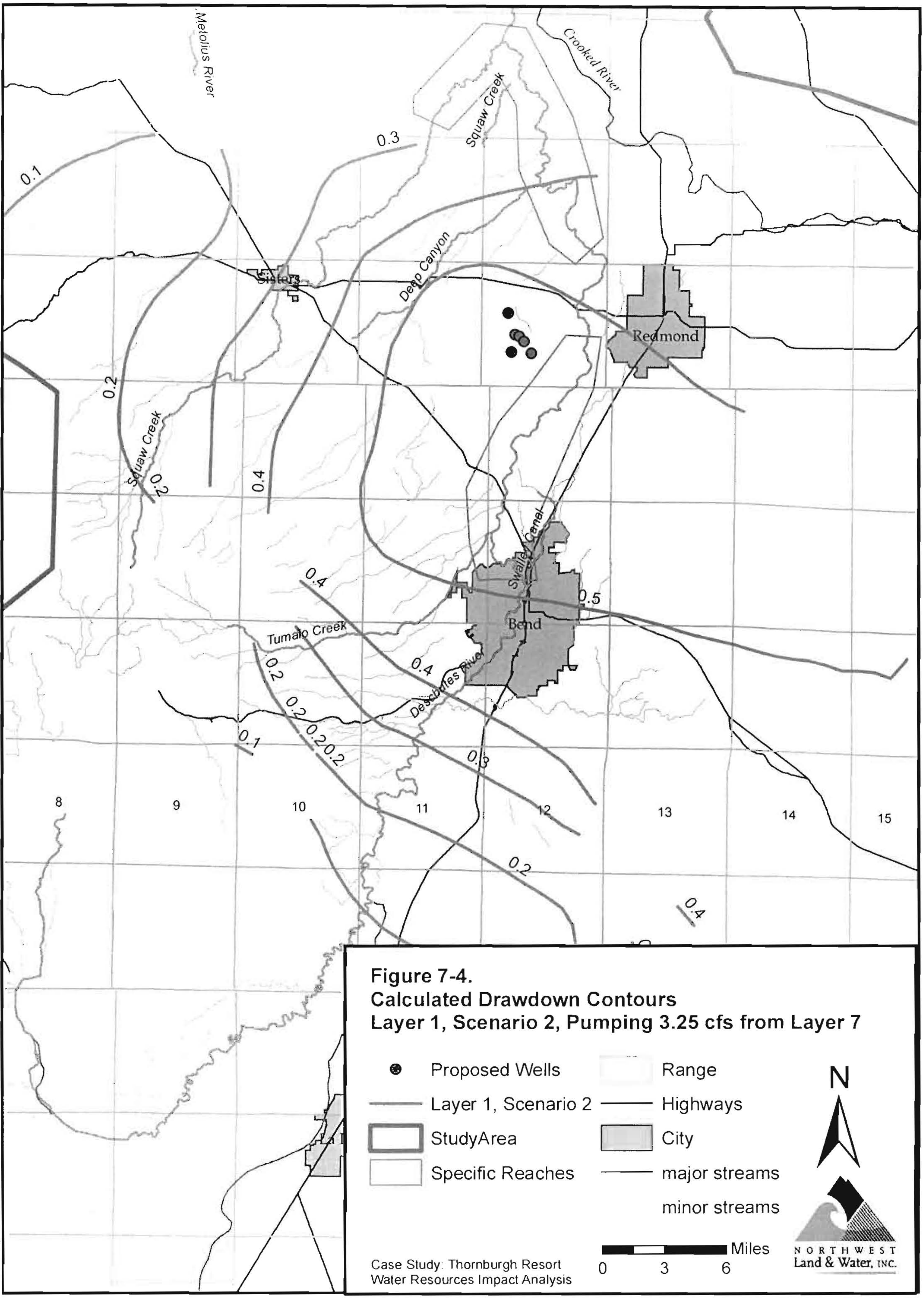


Figure 7-4.
Calculated Drawdown Contours
Layer 1, Scenario 2, Pumping 3.25 cfs from Layer 7

Case Study: Thornburgh Resort
Water Resources Impact Analysis

D:\Projects\Thornburgh\GIS\MXDs\Contours_L1Scen2.mxd

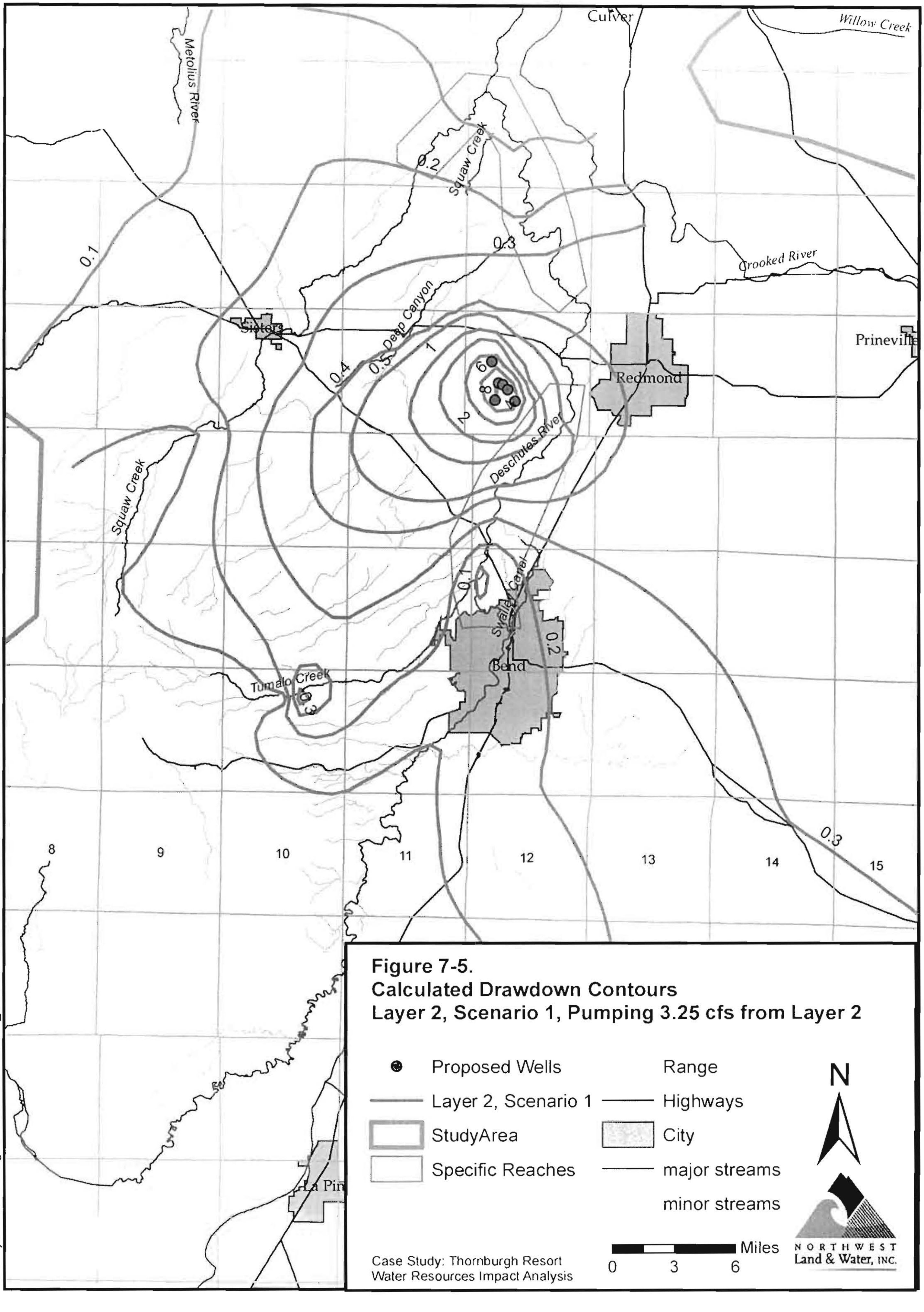


Figure 7-5.
Calculated Drawdown Contours
Layer 2, Scenario 1, Pumping 3.25 cfs from Layer 2

Case Study: Thornburgh Resort
Water Resources Impact Analysis

D:\Projects\Thornburgh\GIS\MXDs\Contours_L2Scen1.mxd

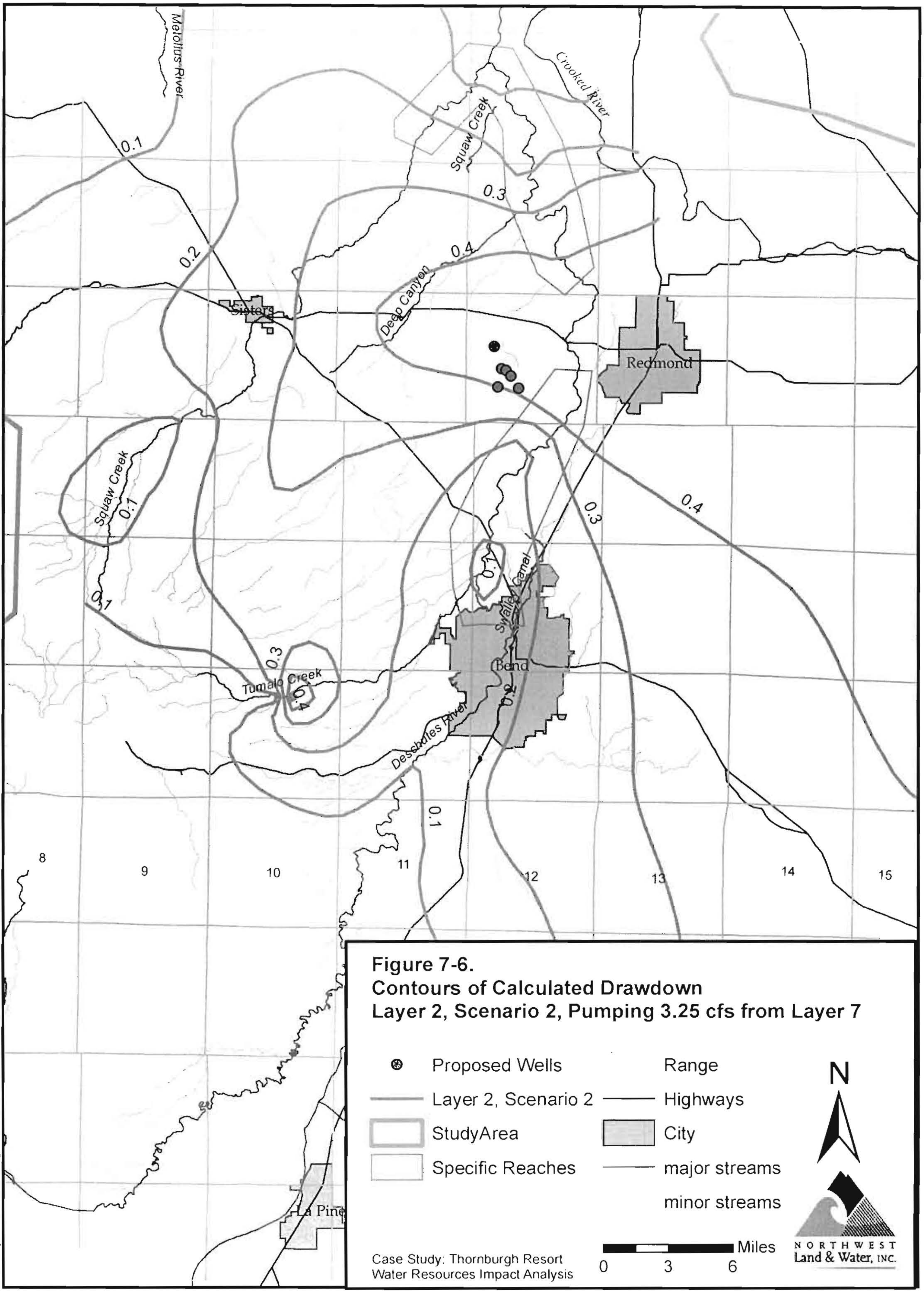


Figure 7-6.
Contours of Calculated Drawdown
Layer 2, Scenario 2, Pumping 3.25 cfs from Layer 7

D:\Projects\Thornburgh\GIS\MXDs\Contours_L2Scen2.mxd

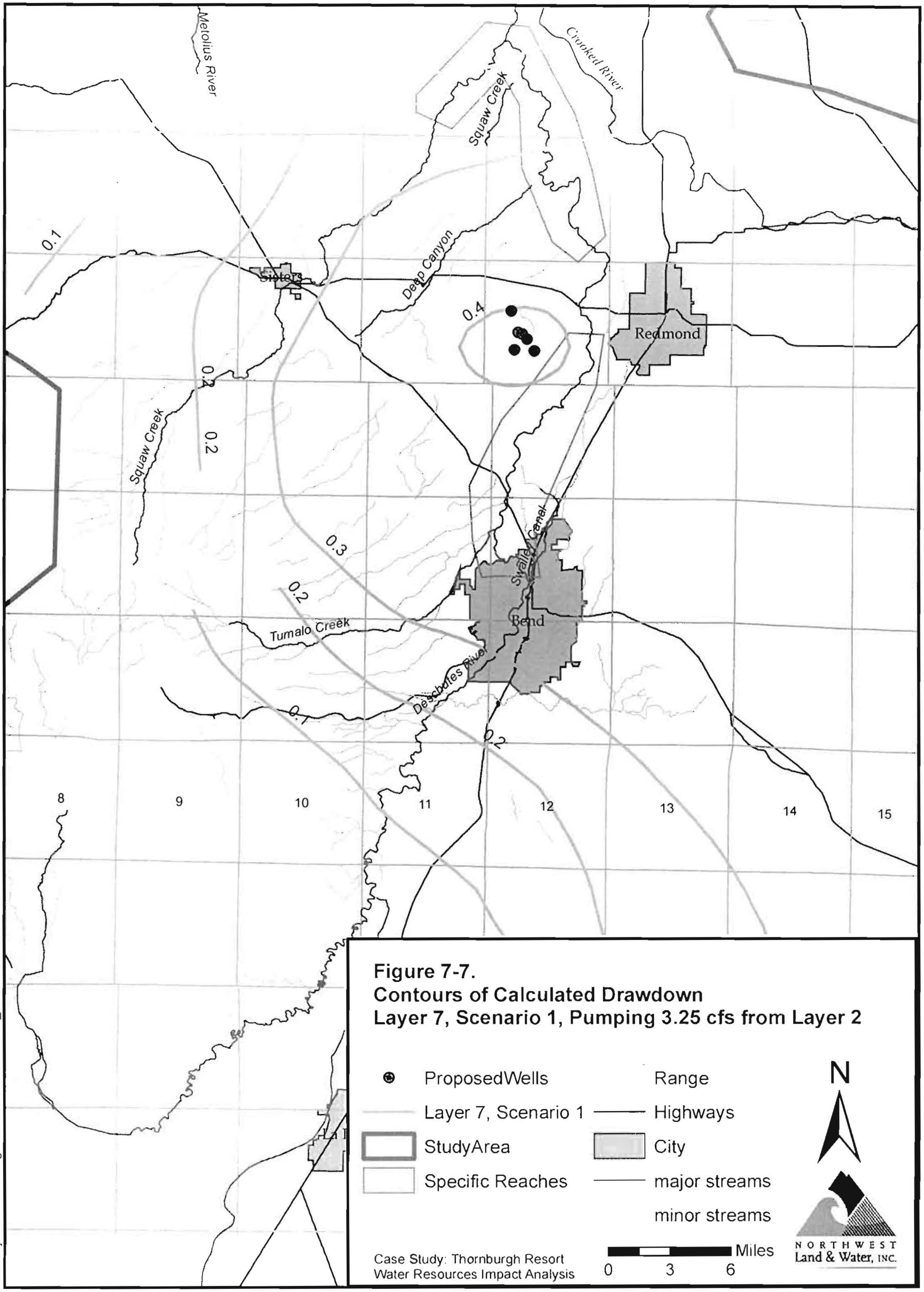


Figure 7-7.
Contours of Calculated Drawdown
Layer 7, Scenario 1, Pumping 3.25 cfs from Layer 2

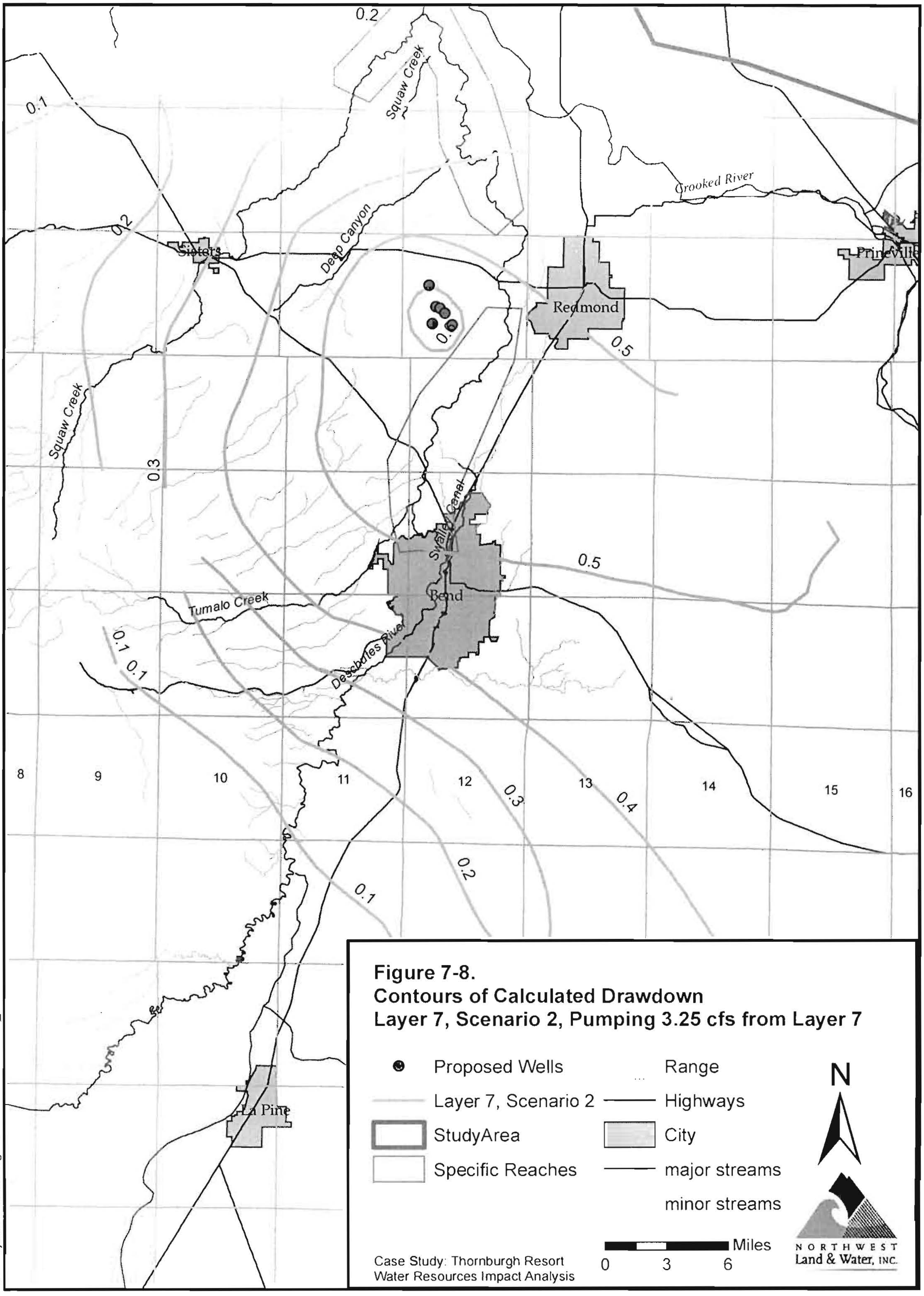


Figure 7-8.
Contours of Calculated Drawdown
Layer 7, Scenario 2, Pumping 3.25 cfs from Layer 7

Case Study: Thornburgh Resort
Water Resources Impact Analysis

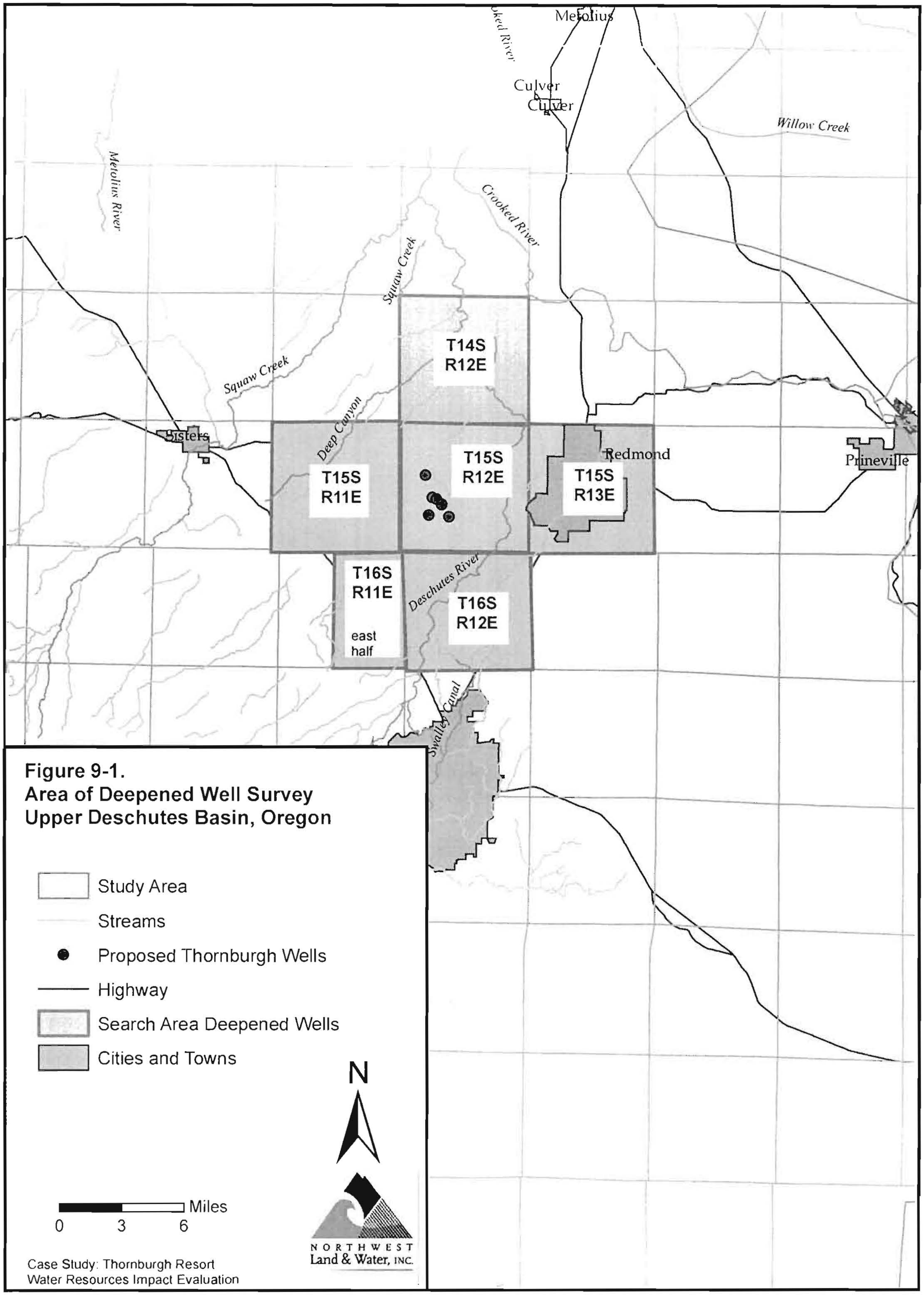


Figure 9-1.
Area of Deepened Well Survey
Upper Deschutes Basin, Oregon

d:\Projects\Thornburgh\GIS\MXDs\DeepenedWellsSearchArea.mxd

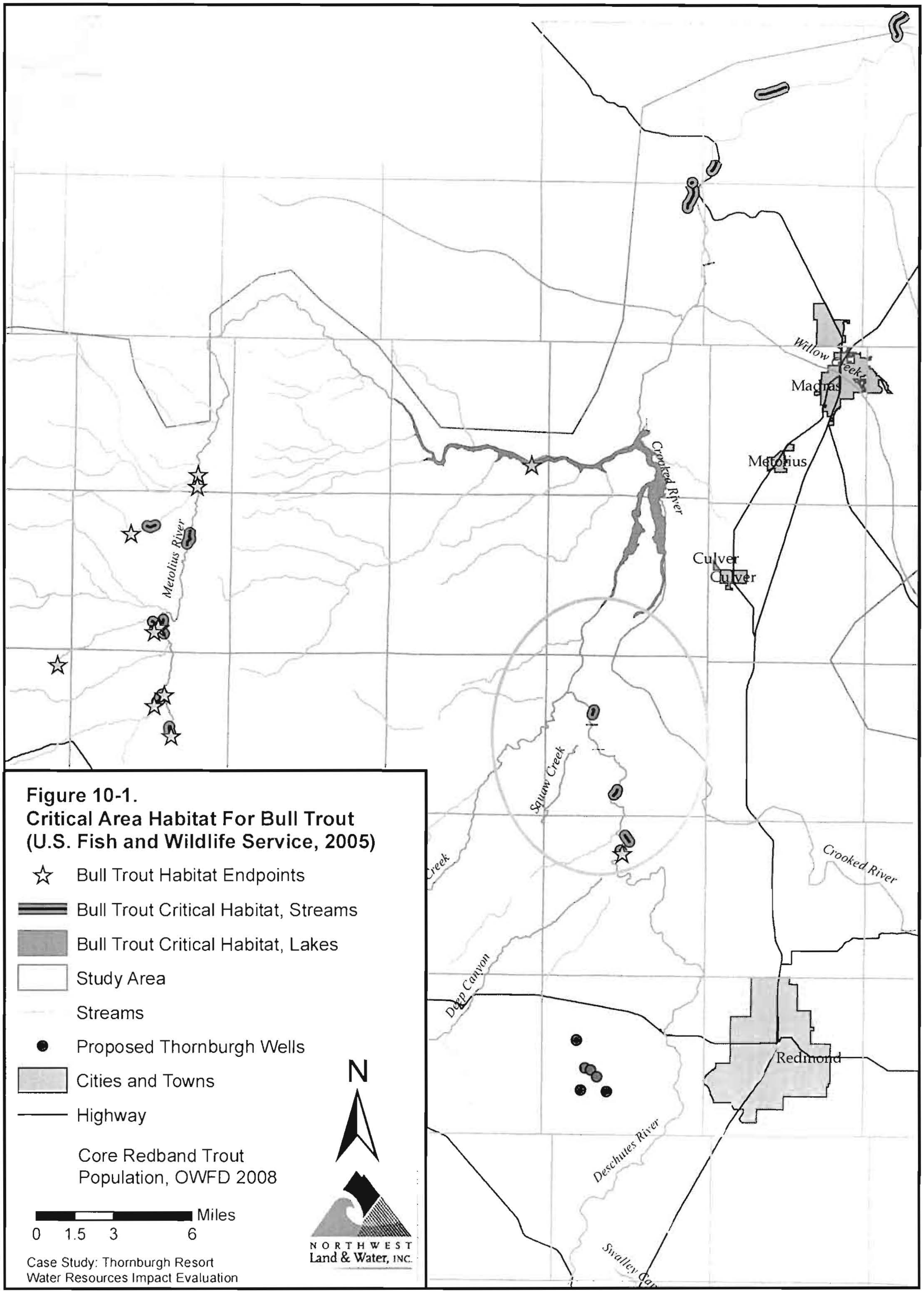
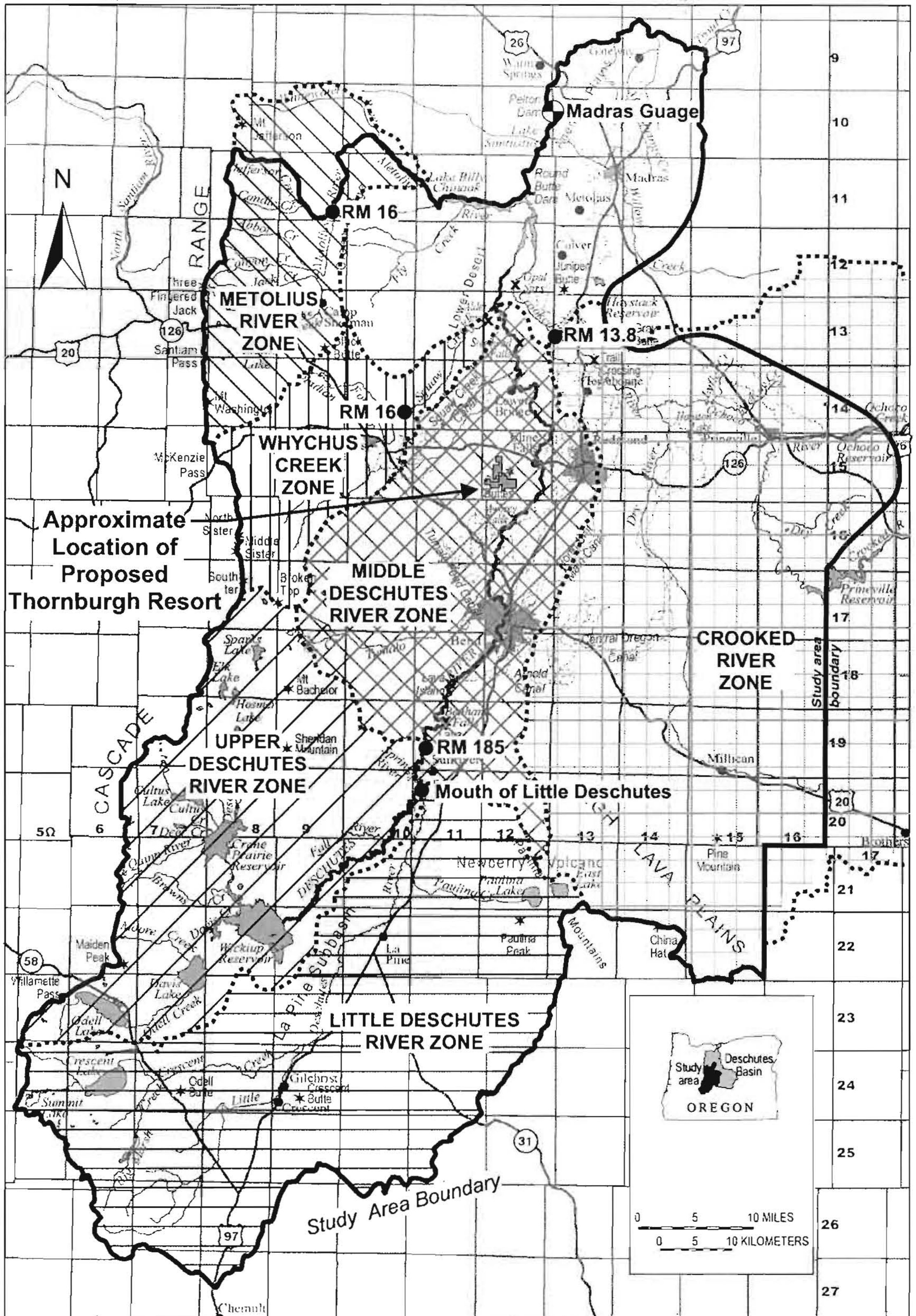


Figure 10-1.
Critical Area Habitat For Bull Trout (U.S. Fish and Wildlife Service, 2005)

d:\Projects\Thornburgh\GIS\MXDs\ThornburghBullTrout.mxd



Base map taken fromGround-Water hydrology of the Upper Deschutes Basin, Oregon, Water-Resources Investigations Report 00-4162. Deschutes Ground Water Zones of Impact taken from Fig. 10, Deschutes Ground Water Mitigation Program, OWRD, Jan 18, 2008 DRAFT. Proposed Thornburgh Resort and Eagle Crest Resort boundaries taken from Hydrology Report Water Supply Development Feasibility Proposed Thornburgh Resort DCC 18.113.050. 2/2/2005.

Figure 11-1
OWRD Deschutes Ground Water Zones of Impact

A Case Study: Thornburgh Resort
Water Resources Impact Evaluation

NORTHWEST Land & Water, INC.

Mark Yinger ASSOCIATES

Appendix A.

Detailed Geologic and Hydrogeologic Description

Appendix A. Detailed Geologic and Hydrogeologic Descriptions

Geology

Clarno Formation

The Eocene Clarno Formation consists of lavas, mudflows, tuffaceous sediments, ash flows, claystone, siltstone and conglomerate of predominantly andesitic composition (Enlows and Parker, 1972; Noblett, 1981; and Peck, 1964). Individual rock units are laterally discontinuous and stream-reworked material is common. Paleosols and saprolites are dispersed throughout the Clarno Formation (Bestland and Retallack, 1964).

John Day Formation

The Oligocene to late Miocene John Day Formation unconformably overlies the Clarno Formation. The John Day Formation consists predominantly of pervasively altered andesitic ash flows, air-fall tuffs and tuffaceous claystone. The formation also includes rhyolite domes, and andesite and basalt lava flows. The John Day Formation material issued from volcanic vents within its the basin of deposition and volcanoes to west in the ancestral Cascades. The tuffaceous material that comprises the bulk of the formation is altered to clay and zeolite minerals. The uplifting of the area along the axis of the Blue Mountain anticline and subsequent erosion has resulted in occurrence of the John Day Formation around the periphery of the Clarno Formation upland. The John Day Formation occurs just east of Prineville and extends north from Smith Rock to Trout Creek at the north end of the UDB. North of Trout Creek the formation is covered by Grande Ronde basalt of the Columbia River Basalt Group. The John Day Formation extends to the west beneath Quaternary to Miocene lava and ash flows and volcaniclastic deposits in the central portion of the UDB to interfinger with volcanic material of the older Western Cascades (Lite and Gannett, 2002; Sherrod et al, 2004). Recent mapping work done by McClaughry (2007), with the Oregon Department of Geology and Mineral Industries (DOGAMI), has identified a large caldera within the John Day Formation centered near Prineville. The Crooked River caldera is filled with zeolitized pumice-lithic tuff and rhyolite flows that issued from vents that ringed the collapse structure. It is likely that there are other calderas associated with the John Day Formation.

The Miocene Picture Gorge basalt lava flows overlie the John Day Formation in the eastern most portion of the UDB. In the Prineville area the Miocene Prineville basalt lava flows overlie the John Day Formation and are overlain by late Miocene and Pliocene basalts lava flows of the Deschutes Formation. North of the UDB the Prineville basalt lava flows interfinger with the Grande Ronde basalt lava flows of the Columbia River Basalt Group over a wide area extending from the Portland to the John Day River (Hooper, et al, 1993). The thickest section (690 feet) is located south of Prineville near Bowman Dam and it is suspected that the basalt erupted from Basin and Range type extensional fractures in this area (McClaughry, 2007).

Deschutes Formation

The late Miocene to Pliocene Deschutes Formation occurs in the area north of Bend and primarily west of the Deschutes River. To the south, north and northeast of Madras the Deschutes Formation laps onto uplands consisting of the John Day Formation. The Deschutes Formation is a complex assemblage of volcaniclastic sedimentary and volcanic rocks consisting of; mudflows, debris flows, sandstone, conglomerate, basalt, basaltic-andesite and andesite lava flows, ash-flow tuff and air-fall ash (Sherrod, et al, 2004). The formation also includes the Cline Buttes rhyolite dome complex, the rhyodacite lava flows near Steelhead Falls and scattered cinder cones marking vents that were sources for lava flows. The volcaniclastic sediments, ash-flows and lava flows primarily derived from the High Cascades were deposited in a basin aligned along the east flank of the High Cascades through which the ancestral Deschutes River flowed. East of the Deschutes River and south of Bend the Deschutes Formation is buried beneath lava flows of the Newberry Volcano. The basin was defined on the east by uplands consisting of the John Day Formation. The western part of the Deschutes Formation is dominated by andesite and basaltic-andesite lava flows deposited on the flanks of the early High Cascades (Smith, 1991). The more fluid basaltic lavas flowed far into the central basin which was being inundated with coarse grained volcaniclastic sediments and ash-flows. The channel of the ancestral Deschutes River and the shallow braided channels of its tributaries were regularly rapidly filled and buried by debris flows related to eruptive events thus forcing streams to establish new channels and profiles and rework earlier deposits. Lava and ash flows that flowed into the central portion of the basin filled shallow sinuous channels.

In the late Miocene to early Pliocene of the High Cascade Mountains subsided into a graben bounded on the east by the Green Ridge fault and by the Horse Creek fault zone on the west. Thus the central portion of the UDB was robbed of its source of volcaniclastic sediments that had inundated the basin (Sherrod, et al, 2004; Smith, 1991). Today the deeply incised canyons of the Deschutes River, Crooked River and tributaries provide excellent exposures of the Deschutes Formation.

Pliocene Volcanic and Sedimentary Rocks

Pliocene volcanics within UDB include basaltic-andesite lava flows that form the shield volcanoes of Little Squaw Back and Squaw Back Ridge; two low buttes north of Sisters. These two small shield volcanoes cap basalt lava flows of the Deschutes Formation. The basalt of Redmond and Dry River are lava flows in the Redmond area and to the east and southeast of Redmond (Sherrod, et al, 2004). These lavas likely erupted from fissure vents southeast of the basin in the High Lava Plains province. Pleistocene to Pliocene sediments include alluvial fan deposits derived from uplands composed of the John Day Formation and Prineville basalt on the lower flanks Powell Butte and to the north of Prineville (Sherrod, et al, 2004).

Quaternary Volcanics

During the Pleistocene a number of pyroclastic eruptions occurred in an area that has been referred to as the Tumalo volcanic center, an area between Bend and Broken Top mountain (Hill and Taylor, 1990). Ash-flow tuffs and pumice air-fall deposits occur west and north of Bend. These deposits overlie Deschutes Formation material and are overlain by Newberry volcano basalt lava flows and andesite and basaltic-andesite lava flows of the High Cascades. Faults of the Sisters fault zone cut the pyroclastic deposits and the overlying lava flows.

The Quaternary volcanic field of the High Cascades and Newberry shield volcano cover large areas in the western and southwestern portions of the UDB. The High Cascades includes the Mount Bachelor volcanic chain consisting of a chain of basaltic-andesite shield volcanoes extending south from Mount Bachelor to the southwest corner of the UDB. The major High Cascade volcanoes include: Broken Top, The Three Sisters, Mount Washington, Three Fingered Jack and Mount Jefferson. There are many smaller vents. Rock types include; basaltic-andesite lava flows and pyroclastics, basalt lava flows and cinder cones, and dacite, rhyodacite and rhyolite lava flows and domes. The vesicular basalt lava flows of the Newberry volcano cover a large area to the east of Bend, extending from the summit crater to just north of Redmond.

Hydrogeology

The properties of earth materials that influence the movement of groundwater are of primary concern. The porosity and the degree to which pores are connected (permeability) in rocks and unconsolidated material are dependant on many factors. Two examples of factors that determine a rocks initial porosity and permeability are the energy of the depositional environment for sediments and the volatile content of erupted magmas. The initial porosity and permeability may be reduce or increased by weathering, hydrothermal alteration and deformational fracturing.

The basement of the UDB groundwater flow system is largely defined by older less permeable rocks that underlie the Miocene to Quaternary volcanics and volcaniclastic sedimentary rocks of the basin. These include the altered upper Eocene to lower Miocene volcanics and volcaniclastic sedimentary rocks of the John Day Formation that extend from the east to interfinger with Miocene to Pliocene volcanics of the ancestral Cascade Range (Fig. 5-1). The John Day Formation also defines much of the eastern and northern lateral boundaries of the groundwater flow system The John Day Formation has very low permeability due to diagenetic and hydrothermal alteration of the original volcanic material, largely ash, to clay and zeolite minerals. The andesite and basaltic-andesite lava flows and intrusives of the ancestral Cascades are pervasively hydrothermally altered resulting in low permeability. The basement of the flow system beneath the Newberry volcano area is also defined at depth by pervasive hydrothermal alteration that has greatly reduce permeability (Lite and Gannett, 2002).

Quaternary volcanic deposits of the High Cascades and the Newberry Volcano are very permeable. The great majority of groundwater recharge occurs in the very permeable Quaternary deposits of the High Cascades and Newberry volcano. The greatest recharge occurs along the Cascade crest where the annual precipitation can locally exceed 100 inches annually. Precipitation and snowmelt rapidly percolate into the fractured lava flows and tephra deposits. To the south of Bend and west of the Green Ridge and Sisters Fault zones the High Cascade and Newberry volcanic deposits are saturated and discharge to spring-creeks. Fall River and the upper Metolius River are classic examples of this discharge.

The leaky network of unlined irrigation canals to the northwest, north and east of Bend which are cut into High Cascade and Newberry volcanics are an important source of recharge. Approximately 46% of the water diverted, primarily from the Deschutes River, into the canals leaks out of the bottoms of the canals (Gannett, et al, 2001). The great majority of the water leaked from the canals returns as groundwater discharges to the Deschutes River and Crooked River in the northern portion of the UDB. A portion of the water leaked from the canals recharges perched aquifers that supply shallower water wells.

The Deschutes Formation is the principal aquifer and the great majority of groundwater in the UDB flows in a northerly direction through it to discharge to the Deschutes River, Metolius River and the lower Crooked River. At the northern end of the UDB the impermeable rising basement rock of the John Day Formation, against which the Deschutes Formation terminates, forces essentially all of the groundwater in the Deschutes Formation to discharge to streams in the three rivers confluence area, at and upstream of Lake Billy Chinook. The groundwater discharge in the confluence area totals approximately 2,300 cubic feet per second (cfs) (Gannett and Lite, 2004).

A generalized model for the deposition of the Deschutes Formation provides insight into the permeability distribution within the Deschutes Formation. The model was initially proposed by Smith (1986) and is referred to in water resource studies of the UDB published by the USGS (Lite and Gannett, 2002; Gannett and Lite, 2004). The model recognizes three depositional environments to the east of the ancestral High Cascade volcanic arc, the primary source area: an arc-adjacent alluvial plane, the ancestral Deschutes River, and the inactive-basin margin (Fig. 5-3). In the arc-adjacent alluvial plain facies the volume of lava flows decrease and the volume of volcaniclastic sediments increase from west to east. The arc-adjacent alluvial plain facies composes the bulk of the Deschutes Formation and it is chiefly composed of volcaniclastic sediments. Generally the grain size of the sediments and therefore, permeability decreases to the east and north in the basin.

The ancestral Deschutes River facies is characterized by channel deposits of the ancient river. These channel deposits consist of very permeable coarse sandstones and conglomerates, and intra-canyon basalt lava flows. The inactive-basin margin facies consists of generally fine grain less permeable sediments deposited along the eastern margin of the basin by streams draining uplands composed principally of the John Day Formation. The inactive-basin margin facies also includes volcaniclastic sediments and air-fall ash of the of the High Cascade volcanic arc province.

A fourth proximal facies constitutes the bulk of the Deschutes Formation along the western and southern margins of the depositional basin consisting primarily of lava flows, flow breccias and coarser tephra (Lite and Gannett, 2002). This permeable facies is composed of material deposited in near proximity to volcanic vents of the High Cascades and Newberry Volcano.

Appendix B.

Selected Water Well Logs for Thornburgh Area

*NOTICE TO WATER WELL CONTRACTOR
The original and first copy of this report are to be filed with the

*WATER RESOURCES DEPARTMENT,
SALEM, OREGON 97310
within 30 days from the date of well completion.

DESC 3324

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

RECEIVED
NOV 13 1979
WATER RESOURCES DEPT
SALEM, OREGON

State Well No. 15S/11E-25bd

State Permit No.

(1) OWNER:

Name Mr. John Susac

Address 45 N.W. Lafayette-Bend, Oreg.97701

(2) TYPE OF WORK (check):

New Well [x] Deepening [ ] Reconditioning [ ] Abandon [ ]

If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:

Rotary [x] Driven [ ]
[illegible] [ ] Jetted [ ]
[illegible] [ ] Bored [ ]

(4) PROPOSED USE (check):

Domestic [x] Industrial [ ] Municipal [ ]
Irrigation [ ] Test Well [ ] Other [ ]

(5) CASING INSTALLED: Threaded [ ] Welded [x]

8" Diam. from +1 ft. to 26 ft. Gage .250"

" Diam. from ft. to ft. Gage

" Diam. from ft. to ft. Gage

(6) PERFORATIONS: Perforated? [ ] Yes [ ] No.

Type of perforator used

Size of perforations in. by in.

perforations from ft. to ft.

perforations from ft. to ft.

perforations from ft. to ft.

(7) SCREENS: Well screen installed? [ ] Yes [x] No

Manufacturer's Name

Type Model No.

Diam. Slot size Set from ft. to ft.

Diam. Slot size Set from ft. to ft.

(8) WELL TESTS: Drawdown is amount water level is lowered below static level

[illegible] a pump test made? [ ] Yes [x] No If yes, by whom?

Yield: gal./min. with ft. drawdown after hrs.

AIR TEST 15 gal./min. with 1 ft. drawdown after 2 hrs.

Artesian flow g.p.m.

Temperature of water 51 Depth artesian flow encountered ft.

(9) CONSTRUCTION:

Well seal—Material used CEMENT

Well sealed from land surface to 26 ft.

Diameter of well bore to bottom of seal 12 in.

Diameter of well bore below seal 8 in.

Number of sacks of cement used in well seal 14 sacks

How was cement grout placed? PRESSURE GROUTED

Was a drive shoe used? [ ] Yes [x] No Plugs Size: location ft.

Did any strata contain unusable water? [ ] Yes [x] No

Type of water? depth of strata

Method of sealing strata off

Was well gravel packed? [ ] Yes [x] No Size of gravel:

Gravel placed from ft. to ft.

(10) LOCATION OF WELL:

County Deschutes Driller's well number

SE ¼ NW ¼ Section 25 T 15-S R. 11-E W.M.

Bearing and distance from section or subdivision corner

(11) WATER LEVEL: Completed well.

Depth at which water was first found 698 ft.

Static level 684 ft. below land surface. Date 10-18-79

Artesian pressure lbs. per square inch. Date

(12) WELL LOG: Diameter of well below casing 8

Depth drilled 752 ft. Depth of completed well 752 ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. Report each change in position of Static Water Level and indicate principal water-bearing strata.

MATERIAL	From	To	SWL
Sand & boulders	0	4	
Frac. lava	4	19	
Gray lava	19	31	
Broken brn. lava(cement)	31	40	
Sed. with clay	40	57	
Tan claystone	57	61	
Brn. lava broken(cement)	61	96	
Brn. claystone	96	183	
Pumice & sediments	183	203	
Conglamerate	203	272	
Broken lava	272	277	
Cinders (cement)	277	294	
Brn. lava (cement)	294	302	
Dense gray lava	302	320	
Sediments & clay	320	366	
Gray lava	366	373	
Sed. & clay	373	384	
Gray lava	384	392	
Cont. next page			

Work started 9-26-79 19 Completed 10-19-79 19

Date well drilling machine moved off of well 10-19-79 19

Drilling Machine Operator's Certification:

This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.

[Signed] [signature] (Drilling Machine Operator) Date 11-7, 1979

Drilling Machine Operator's License No. 1098

Water Well Contractor's Certification:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

Name REED'S WELL DRILLING (Person, firm or corporation) (Type or print)

Address 20219 Meadow Lane-Bend, Oreg.97701

[Signed] [signature] (Water Well Contractor)

Contractor's License No. 443 Date 11-7-79, 19

(USE ADDITIONAL SHEETS IF NECESSARY)

SP*45656-119