Assessing the Impact of Mitigation on Streamflow in the Deschutes Basin

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Introduction

Surface water in the upper Deschutes basin is over-allocated in most areas at most times of the year with many in-stream requirements being met less often than expected under the Water Allocation Policy adopted by the Water Resources Commission in July 1992. As a result, opportunities for new surface water appropriation in the basin are limited, and attention has turned to groundwater as a source for new appropriations. However, groundwater and surface water are directly linked in the Deschutes basin. In many locations, groundwater is a primary source of surface water. Where this is the case, withdrawals from groundwater have a direct impact on streamflows.

In order to prevent further diminishment of the surface water resource due to groundwater withdrawals, the Oregon Water Resources Commission adopted the Deschutes Groundwater Mitigation Rules (OAR Chapter 690, Division 505) in September 2002. The rules require that new allocations of groundwater be mitigated to reduce their effect on surface water flow. Because it is expected that the activities allowed under the rules will have some effect on streamflow and may impact how often in-stream requirements are met, the rules require that the Oregon Water Resources Department (OWRD) monitor and evaluate the effects of mitigation and groundwater allocation on streamflow throughout the basin.

The mitigation rules require that in-stream requirements in the basin be met at least as often after mitigation as before. The impacts of mitigation on streamflow, then, are measured as changes in the frequency that the in-stream requirements are met. Impacts may be either positive or negative depending on the type of activity, location, and season of the year.

The “before mitigation” or baseline condition of streams in the Deschutes basin is determined from streamflows measured during water years 1966 to 1995. This period is after all reservoirs were built and before the Department included a condition on groundwater permits subjecting them to possible regulation under the State Scenic Waterway Act, i.e., the so called “7J condition” (OAR 690-310-260 (9)(g)). Water rights with the 7J condition are discussed in a later section. With the adoption of the mitigation rules, the OWRD now adds a further condition that a groundwater right issued with mitigation will not be subject to regulation as long as the mitigation is maintained.

A Numerical Model

A computer program has been developed by the OWRD to numerically estimate (i.e., model) the effects of mitigation and groundwater allocation and to calculate changes in the frequency in-stream requirements are met as a result of these effects. The model is based on historic streamflow for water years 1966 to 1995.

In the model, the effects of mitigation and groundwater allocation are estimated, and the historic time series of streamflows is modified according to those effects. The percent of time the in-stream requirements are met is calculated for both the original and modified time series. Whether an in-stream requirement is met is determined on a daily basis (using *mean* daily flows as the basis for comparison) and is reported as the percent of days the in-stream requirements are met both monthly and annually. The model also tracks changes in streamflow rate. These statistics also are reported monthly and annually.

Scope of the Model

The numerical model assesses the impact of various mitigation activities on streamflow at eight locations on the Deschutes River and its tributaries. A long-term gaging station or a combination of stations, with continuous record for water years 1966 to 1995 represents streamflow at each location. Each location is in a reach of river affected by one or more in-stream requirements. The in-stream requirements may be the result of an in-stream water right (ISWR), a scenic waterway (SWW), or a treaty with the Warm Spring tribes (Treaty). Some locations may be subject to more than one requirement. It is important to note that these requirements are not additive – only the largest requirement is considered in each case. Finally, mitigation activities and allocation of groundwater are expected to impact streamflow at each location.

Another type of in-stream requirement results from the lease or transfer of an out-of-stream water right to in-stream. Many of the mitigation credits created under the mitigation rules will be the result of such leases and transfers. While the in-stream requirements discussed in the previous paragraph are not additive, the transferred in-stream water rights are additive among themselves. However, they are not usually additive with the other in-stream requirements. When occurring in the same stream reach, a leased or transferred right typically replaces the other type of requirement. The benefit to the stream derives from the earlier priority date of the leased or transferred right. Generally, a transferred in-stream right is much smaller than a non-additive in-stream requirement and replaces only part of it.

Several other long-term gaging stations are located in the Deschutes basin but are not considered in the analysis. Although these gages occur in river reaches with in-stream requirements, they are not suitable for a variety of reasons. In some cases, streamflow at the gaging station does not adequately represent streamflow for the reach (e.g., there are unaccounted for diversions). In other cases, the stations are high in the watershed and impacts from mitigation or groundwater withdrawals are not expected.

The eight locations are shown in Table 1 and Figure 1. Some locations are represented by the sum of streamflows at two or more gaging stations. The in-stream requirements for the eight locations are given in Table 2.

Modeling Versus Real Time Monitoring of Streamflow

It has been suggested that the effects of mitigation and groundwater allocation be determined by real time monitoring of streamflow rather than using a numerical model.

Real time monitoring of streamflows is not used for three reasons: 1) there must be a basis for comparison, 2) it may take many years for the effects of a mitigation project or a groundwater allocation to be fully realized, and 3) activities in the basin other than mitigation may affect streamflow.

In the first case, real time data cannot be immediately compared to a baseline condition. Natural variations in streamflow due mostly to changes in weather from season to season and year to year make this impossible. Table 4 shows the percent of days the in-stream requirement was met at the USGS gaging station located on the Deschutes River just below Pelton Dam near Madras for the period 1966 to 1995. The percent of days varies from 28.8 percent in 1992 to 100 percent in 1984.

Changes in the percent of days in-stream requirements are met due to another cause, say mitigation activities or groundwater allocation, would be hard to determine from year to year. The changes would be masked by natural variation. Unfortunately there is no

Table 1. Deschutes Basin locations where the impacts of mitigation activities are evaluated.

Location	Representative Gaging Station(s)
Deschutes River at the mouth	14103000
Deschutes River below Pelton Dam	14092500
Metolius River at Billy Chinook	14091500
Deschutes River downstream of Bend	14070500
Deschutes River upstream of Bend	14070500 + 4 canals *
Little Deschutes River at mouth	14063000
Deschutes River below Fall River	14056500 + 14057500
Deschutes River below Wickiup Dam	14056500

* The four canals are the DCMID (14068500), the North Unit Main (14069000), the North (14069500), and the Swalley (14070000).

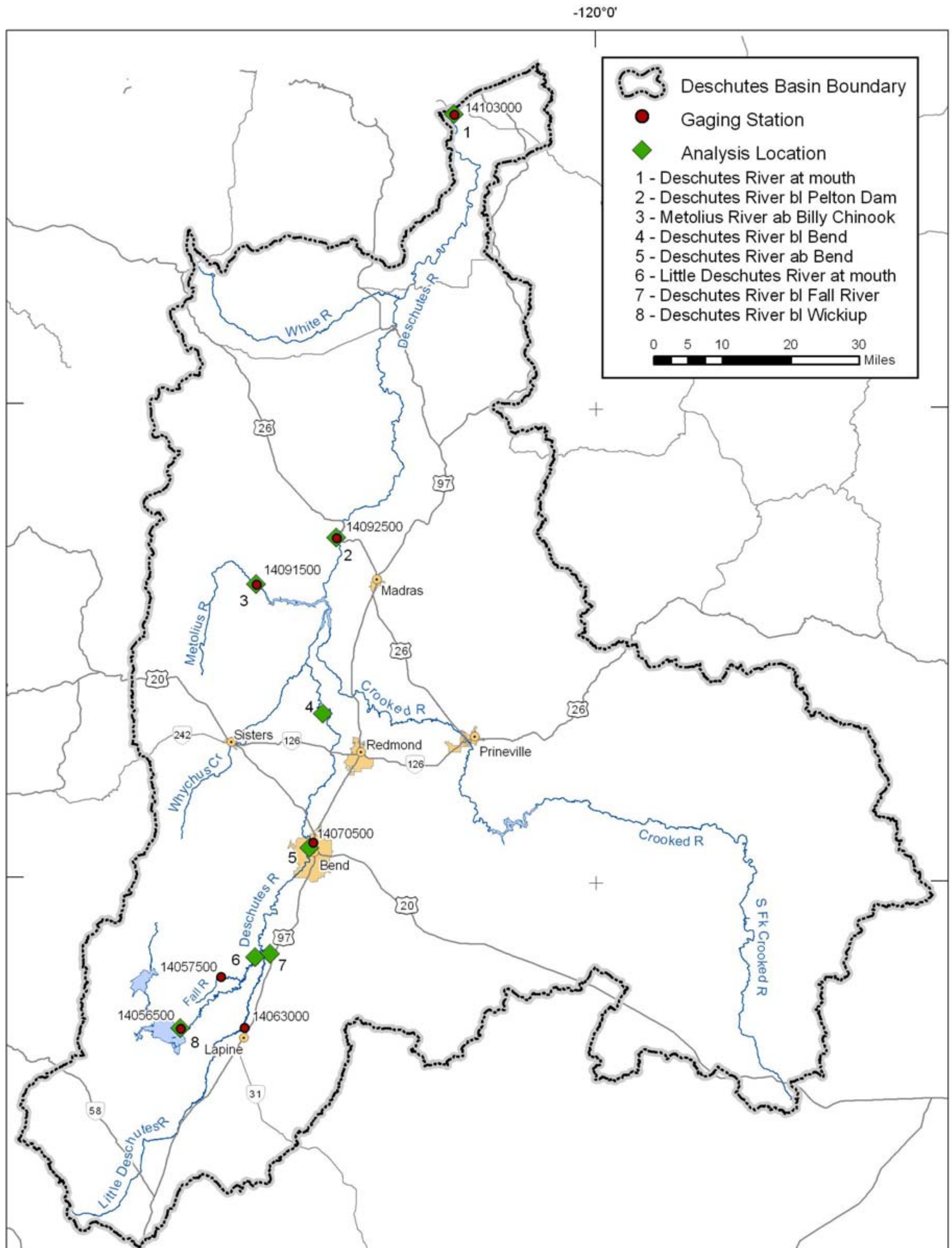

Figure 1. Deschutes Basin locations where the impacts of mitigation activities are to be evaluated.

Table 2. In-stream requirements, in cfs, at each of the eight analysis locations in the Deschutes Basin.

Gage(s)	14103000	14092500	14091500	14070500 Downstream	14070500 + 4 canals	14063000	14056500 + 14057500	14056500
Type of in-stream requirement	SWW	SWW	Treaty	SWW	SWW	ISWR	SWW	SWW
Zone of impact	N/A	General	Metolius River	Middle Deschutes River	Middle Deschutes River	Little Deschutes River	Upper Deschutes River	Upper Deschutes River
Jan	4500	4500	1150	500	660	200	400	400
Feb	4500	4500	1150	500	660	200	400	400
Mar	4500	4500	1160	500	660	236	400	400
Apr	4000	4000	1160	500	660	240	500	500
May	4000	4000	1240	250	660	240	500	500
Jun	4000	4000	1200	250	660	200	500	500
Jul	4000	4000	1170	250	660	126	500	500
Aug	3500	3500	1140	250	660	74.5	500	500
Sep	3500	3500	1100	250	660	92.2	500	500
Oct	3800	3800	1080	500	660	116	500	500
Nov	3800	3800	1140	500	660	164	400	400
Dec	4500	4500	1110	500	660	196	400	400

Table 3. Percent of days the in-stream requirement is met by month in the Deschutes River below Pelton Dam (Gaging Station 14092500) - for the period, water years 1966 to 1995.

Month	Percent of days for each month for all years	Average number of days per month for all years
1	64.7	20
2	63.0	18
3	67.8	21
4	71.4	21
5	58.8	18
6	55.6	17
7	41.0	13
8	98.2	30
9	66.8	20
10	81.1	25
11	97.2	29
12	66.1	21
Annual	69.3	253

good way to remove or compensate for the natural variation.

The long-term percent of days the in-stream requirements are met, however, could reasonably be expected to be about the same for any other comparable 30-year period. In comparing a 30-year period with mitigation activity and a 30-year period without mitigation activity, we could reasonably conclude that differences in the long-term percent of days between the two periods are due to the effects of mitigation and groundwater allocation. Unfortunately, a comparison using real time flows could be made no sooner than 30 years from now.

In the second case, the effects of some mitigation activities and groundwater allocations may not be fully realized for many years. Some delay will result from the time it takes to implement the activities, but more so because of the time it will take for changes to propagate through the groundwater system. Even if it were possible to monitor the effects of mitigation in real time, the time delay in the full realization of those effects

Table 4. Percent of days the in-stream requirement is met annually in the Deschutes River below Pelton Dam (Gaging Station 14092500).

Year	Percent of days per year	Average number of days per year
1966	58.1	212
1967	53.7	196
1968	35.0	128
1969	56.4	206
1970	66.6	243
1971	84.9	310
1972	94.3	344
1973	63.3	231
1974	95.1	347
1975	99.7	364
1976	99.7	364
1977	54.0	197
1978	82.2	300
1979	69.9	255
1980	59.3	216
1981	64.9	237
1982	99.7	364
1983	99.5	363
1984	100.0	365
1985	94.2	344
1986	92.9	339
1987	80.0	292
1988	59.3	216
1989	69.9	255
1990	45.2	165
1991	28.8	105
1992	28.7	105
1993	59.2	216
1994	31.0	113
1995	54.5	199
Long Term	69.3	253

would mean that decisions would be made about further mitigation and allocation of groundwater with the full effects of already approved activities either under- or over-estimated, respectively. Using a model based on historic streamflow provides a basis for comparison and allows us to compute the effects of mitigation at full realization.

In the third case, activities other than those related to mitigation may affect streamflow. A number of activities such as conservation projects, conserved water projects, aquifer storage, or allocation of stored water could happen outside of the scope of the mitigation program.   Even if real time monitoring were otherwise possible, it would not be possible to discriminate between the effects of mitigation activities and other activities that impact streamflow.

Modeling the Groundwater Surface Water Interaction in the Deschutes Basin

Groundwater and surface water are significantly interconnected in the Deschutes basin with groundwater discharge to surface water contributing substantially to streamflow. A basin-wide groundwater system provides much of the discharge to surface flow. This regional system is recharged primarily from three sources (Gannet et al. 2000): 1) about 3,500 cfs from direct precipitation on the basin[1], 2) 850 cfs from adjacent basins by way of inter-basin flow, and 3) 490 cfs from irrigation return flows and canal leakage for projects near Bend, Redmond, Madras, Prineville and Sisters.

Most of the regional flow of groundwater discharges to the Crooked and Deschutes Rivers just above Lake Billy Chinook and to Lake Billy Chinook itself. This discharge plus the streamflow from the Metolius River average about 4,000 cfs - nearly all of the summer streamflow in the lower Deschutes.

Local discharge from groundwater plays an important role in the basin. See Gannet et al. (2000) for information about stream reaches with significant local groundwater

[1] Almost all of this recharge occurs in the Cascade Mountains.

discharge. Of interest here is assigning the impact of withdrawals from groundwater to discharge in an appropriate stream reach. Does the groundwater withdrawal affect discharge to a local stream reach or does it affect the regional discharge near Lake Billy Chinook?

The OWRD defines seven ‘zones of impact’ to describe watersheds that include and are above areas (i.e., river reaches) of significant groundwater discharge to surface water. One is the regional or general zone of impact near Billy Chinook (Figure 2). The other six local zones are: 1) the Crooked River above river mile 13.8, 2) the Metolius River above river mile 28, 3) the Middle Deschutes River above river mile 125, 4) Whychus Creek above river mile 16, 5) the Upper Deschutes River above river mile 185, excluding the Little Deschutes, and 6) the Little Deschutes River above the mouth (Figures 3 to 8, respectively).

Also shown on Figures 2 to 8 are the locations where changes in streamflow are analyzed and the locations of the affected in-stream requirements. Note that some zones of impact have more than one analysis location.   Conversely, the Whychus Creek and the Crooked River zones of impact are not represented at all, as there is not a suitable gaging station for either zone.

For the Whychus Creek zone, the one long-term gage in the zone, Whychus Creek near Sisters (14075000), is located above the expected impacts of mitigation or groundwater withdrawals. Although the major diversion from Whychus Creek (the Squaw Creek Irrigation District Canal) is gaged and could be used to ‘correct’ the record for the gage, another 20 cfs or so of diversion is unaccounted for. For the Crooked River zone, a gaging station is located at an appropriate location (just below Osborne Canyon), but its period of record does not coincide with the selected base period, 1965 to 1995.

The effects of groundwater withdrawal on surface water depend on the location of groundwater discharge. Generally, we assume that shallow wells will impact locally within a zone and that deeper wells will impact regionally near Lake Billy Chinook.

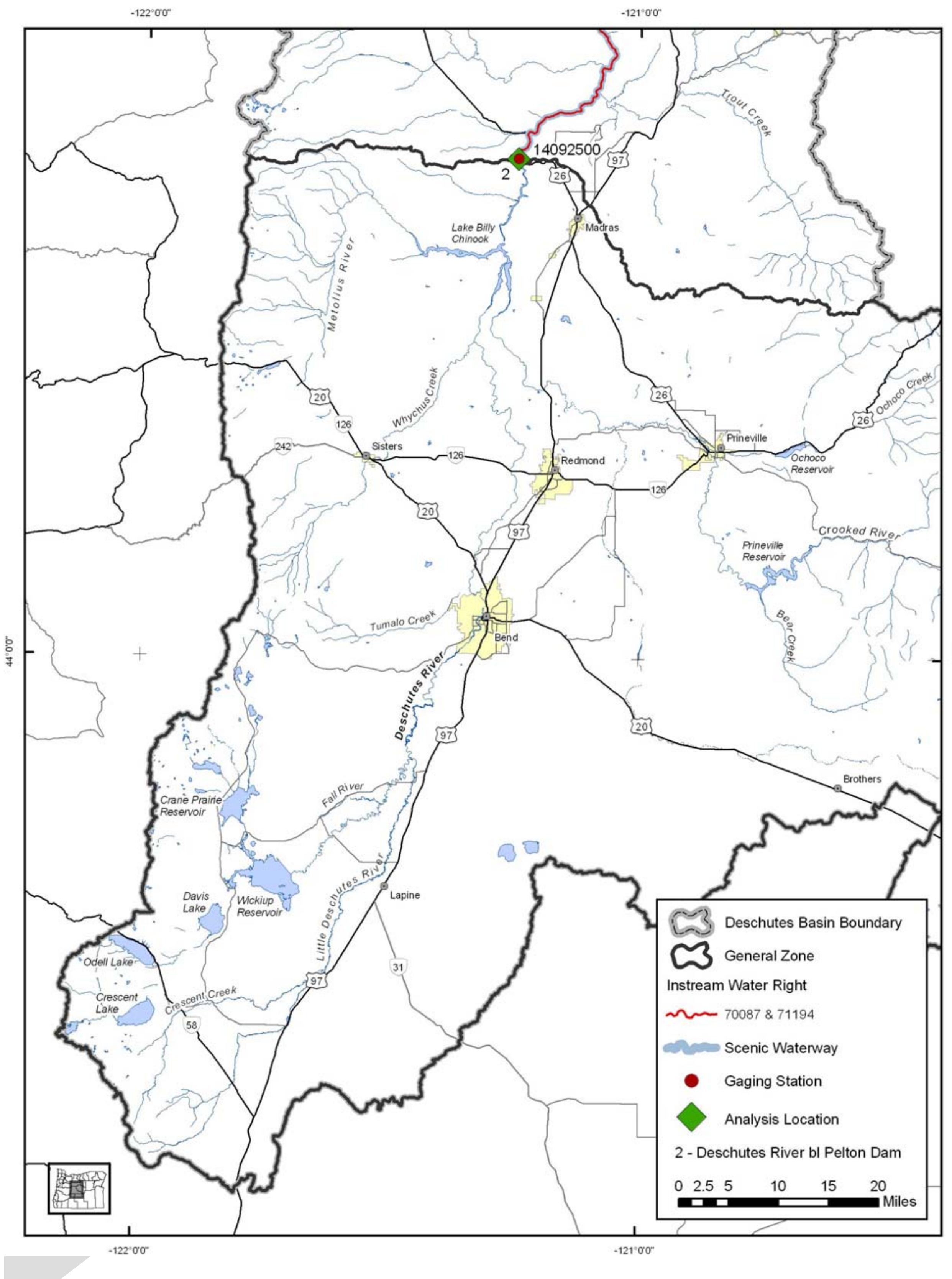

Figure 2. General zone of impact.

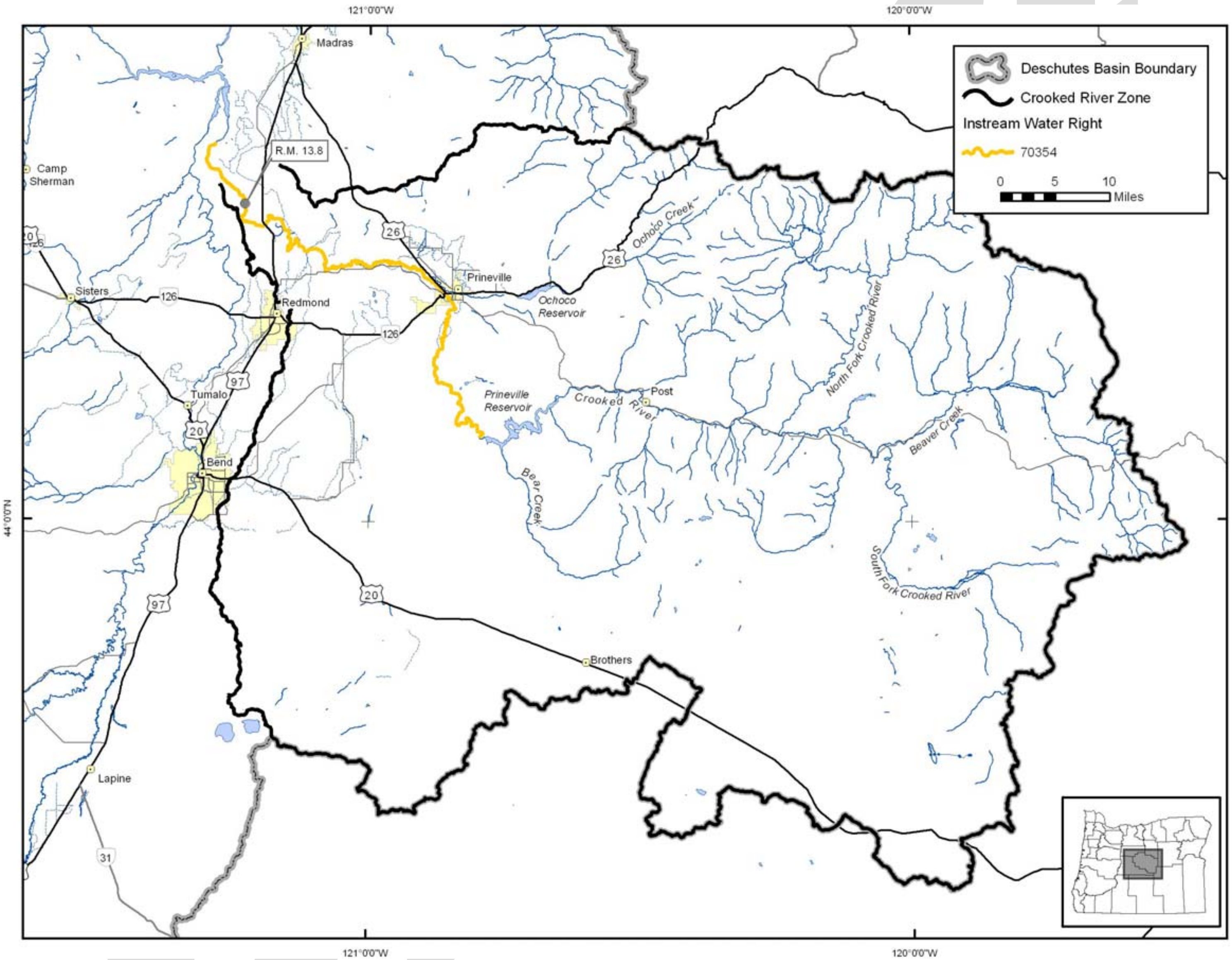

Figure 3. Crooked River zone of impact.

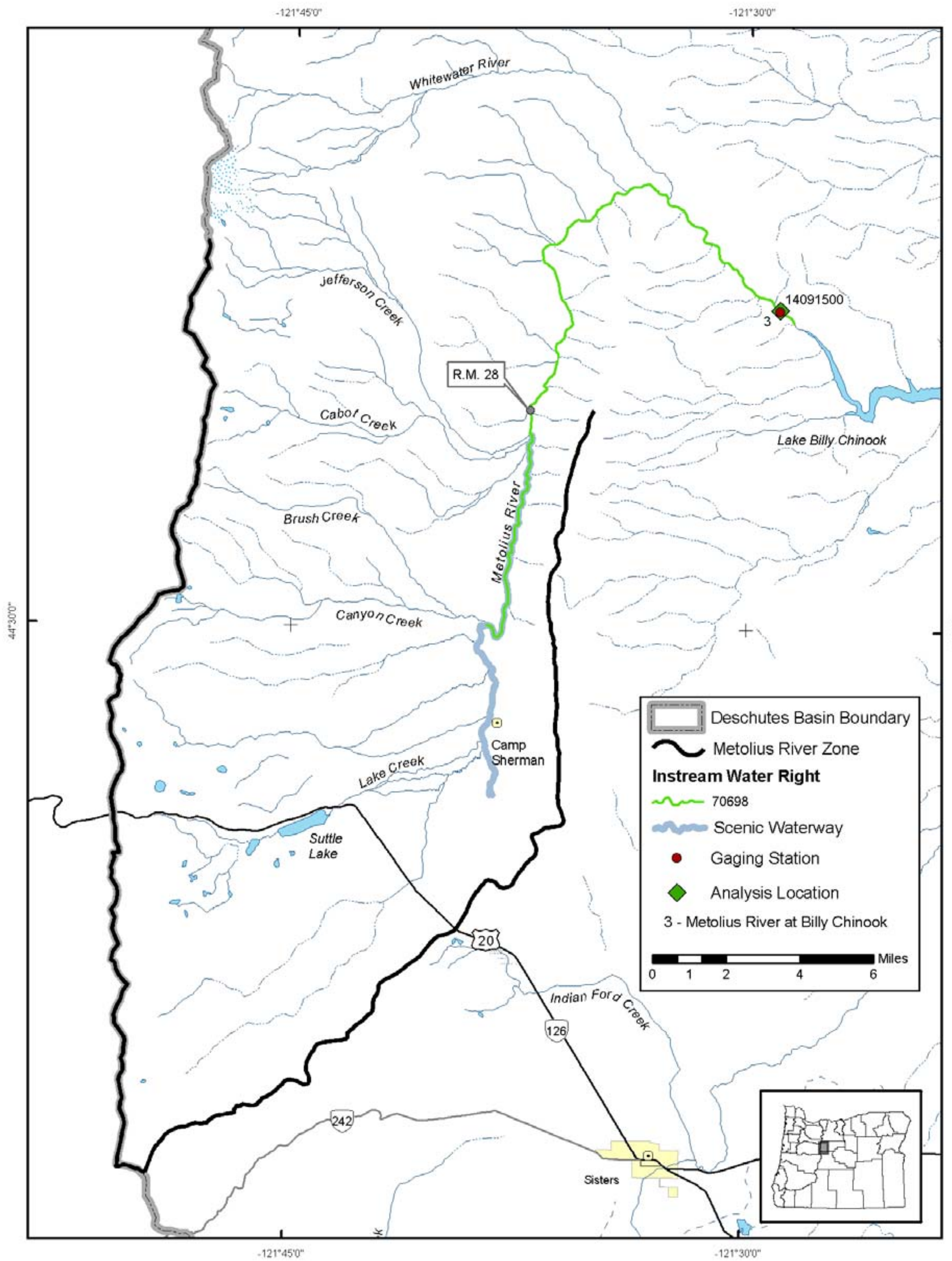

Figure 4. Metolius River zone of impact.

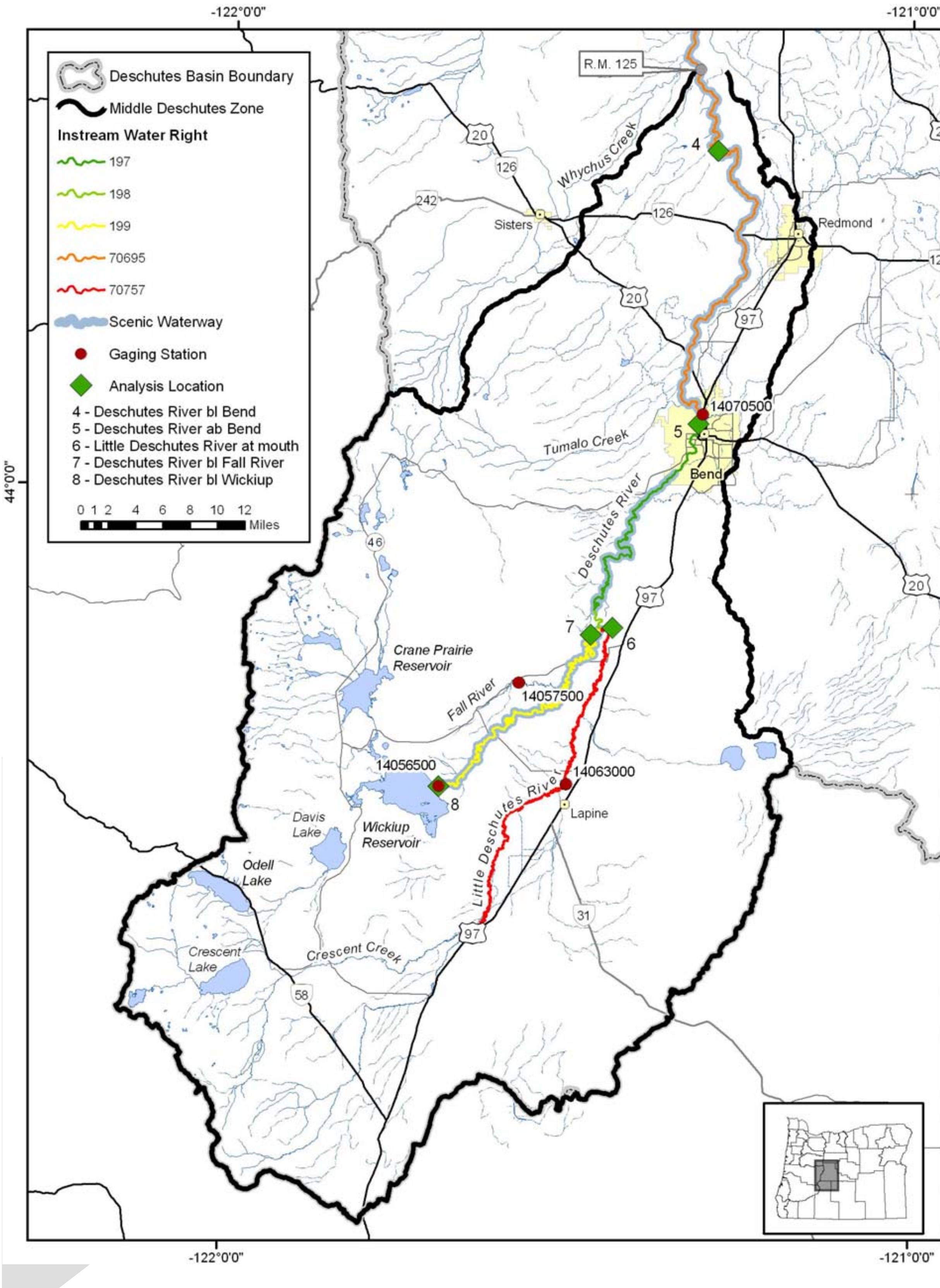

Figure 5. Middle Deschutes River zone of impact.

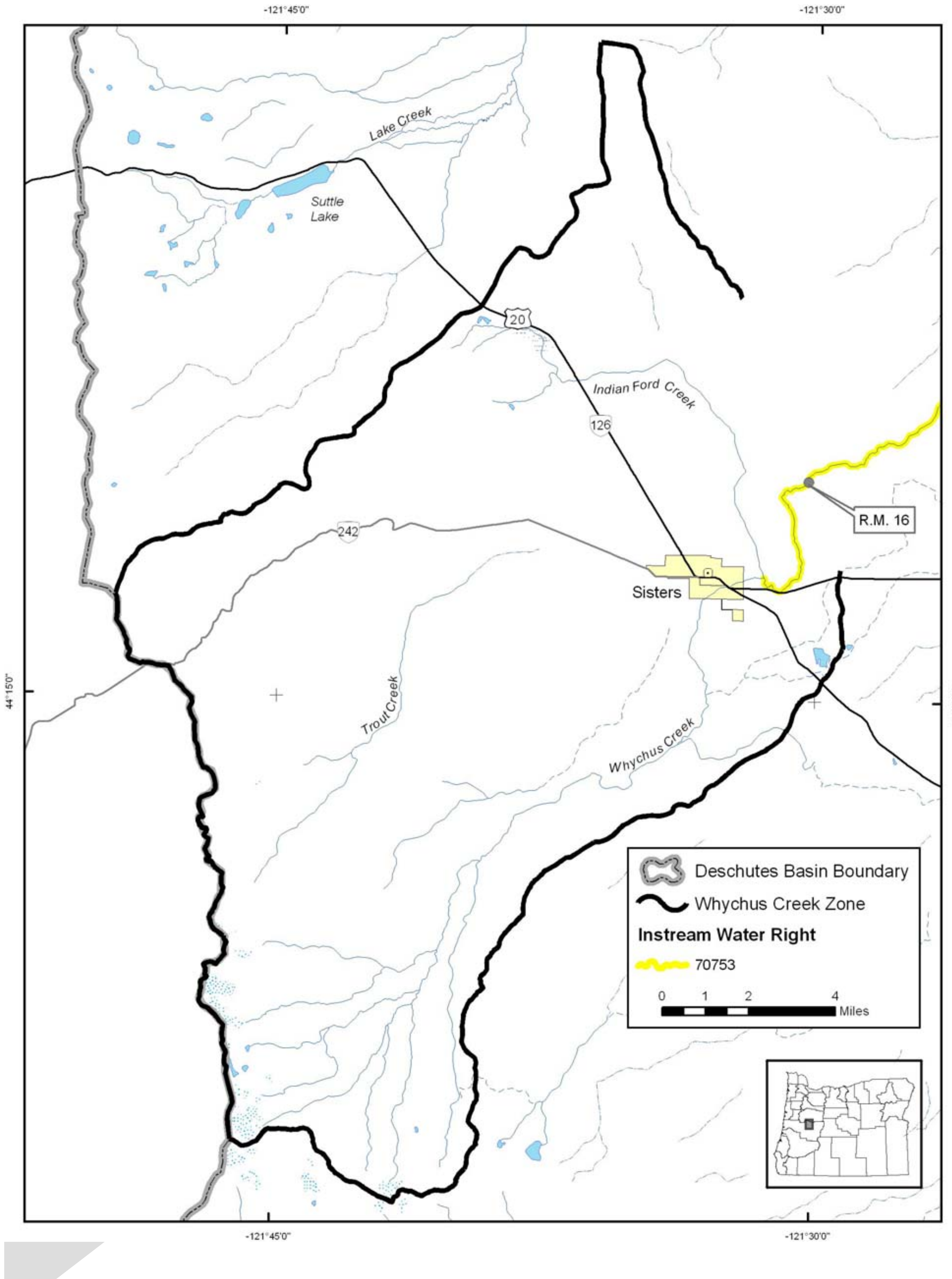

Figure 6. Whychus Creek zone of impact.

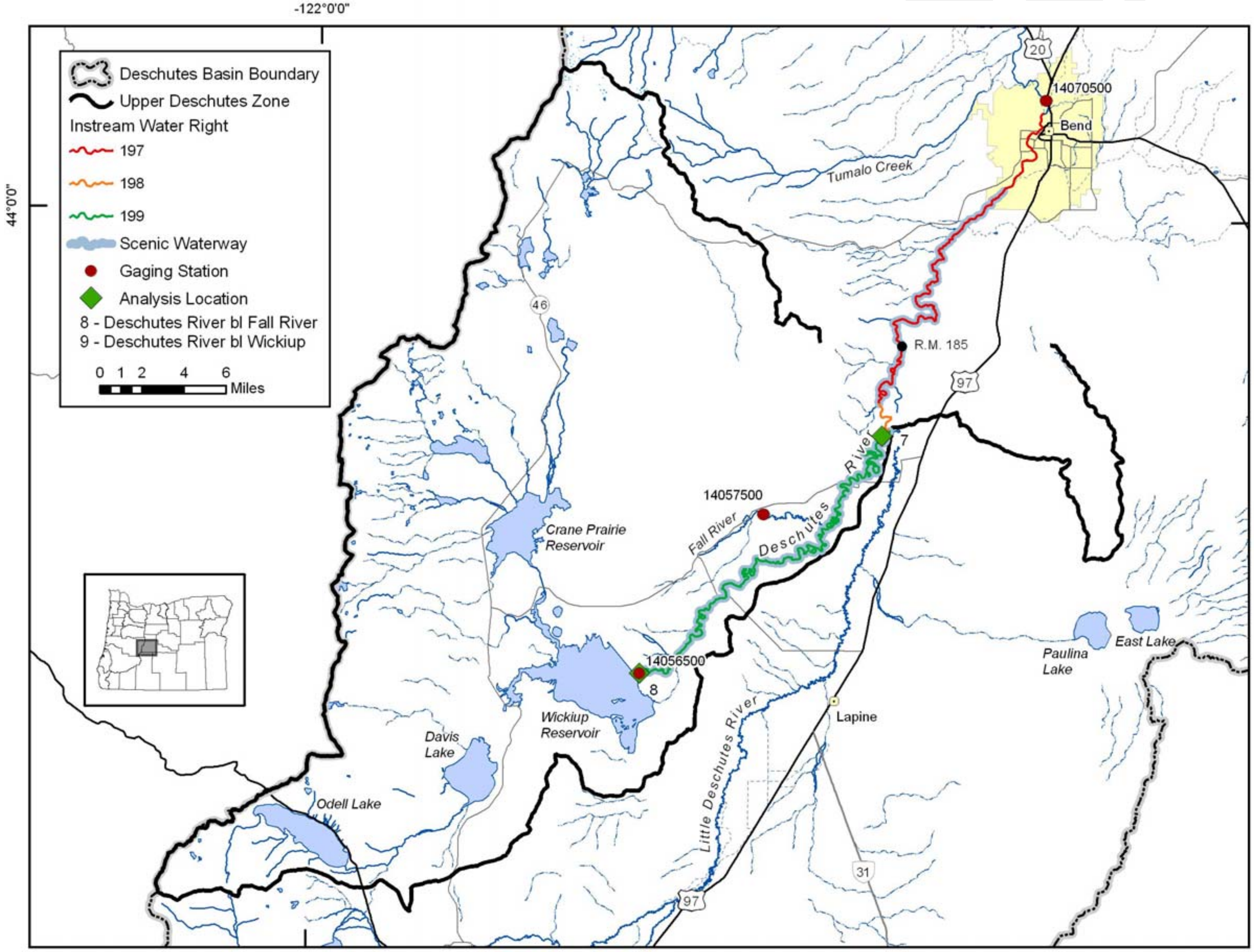

Figure 7. Upper Deschutes River zone of impact.

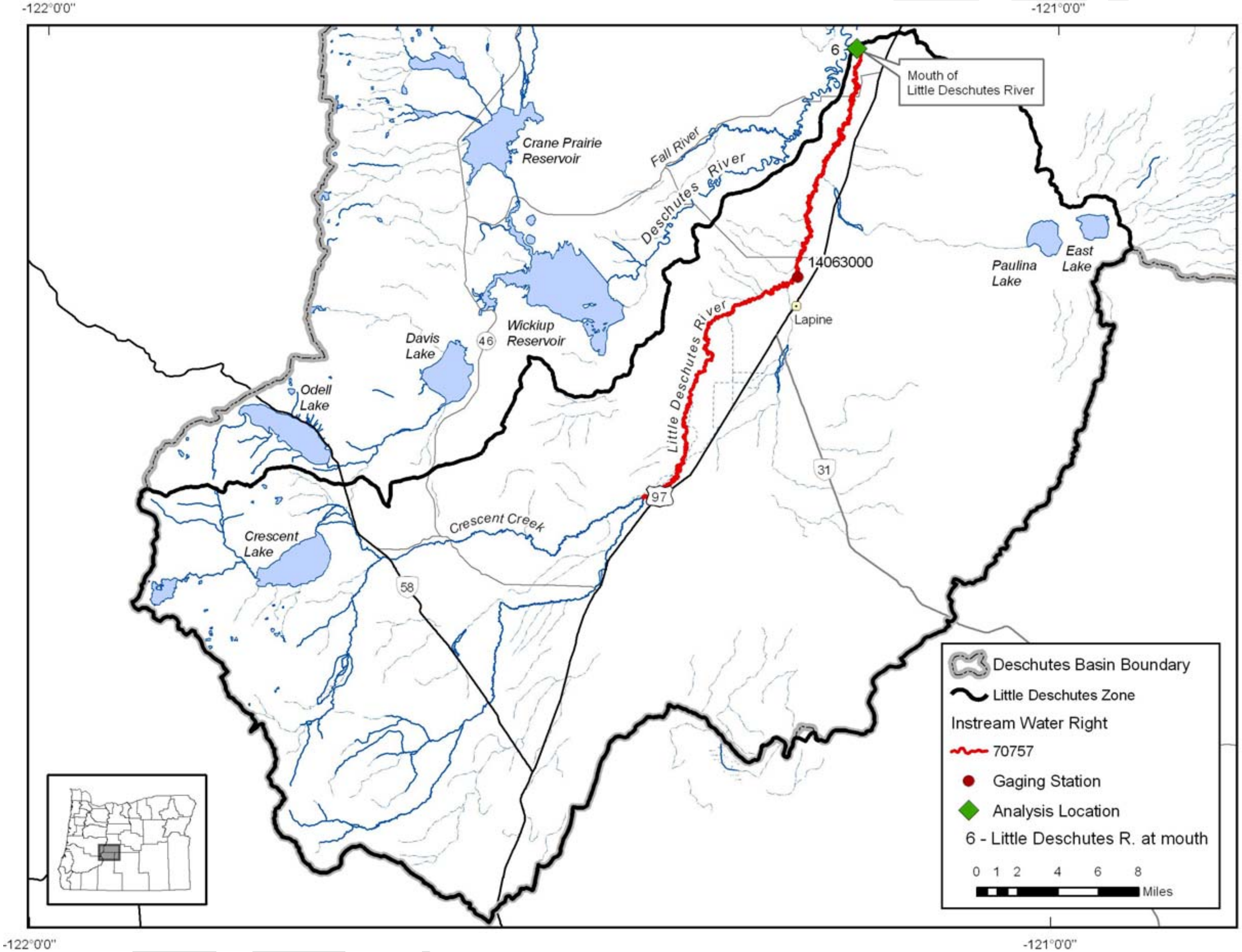

Figure 8. Little Deschutes River zone of impact.

The OWRD's groundwater staff make the actual determination of the zone of impact for each new appropriation. Based on that determination, the mitigation model assigns the effects of groundwater withdrawals to the correct stream reach.

In some cases, more than one zone of impact may be affected. In these cases, the effects of the mitigation project or the groundwater withdrawal will be distributed among the affected zones of impact.

Description of the Numerical Model

The model is based on historic mean daily streamflows at the various gaging stations. The effects of mitigation and groundwater allocation are estimated and the historic time series of streamflows are modified according to those effects. Streamflows are compared to the in-stream requirement at each location. The existing or baseline condition is based on the actual streamflow record. The impacted condition is based on the actual streamflow record modified by the estimated effects of mitigation and groundwater use. Whether an in-stream requirement is met is determined on a daily basis (using *mean* daily flows as the basis for comparison) and is reported as the percent of days the in-stream requirements are met both monthly and annually.

Water years 1966 to 1995 were chosen to represent the baseline condition. This time period is after completion of all reservoirs and prior to any ground water withdrawals subject to regulation under the State Scenic Waterway Act. The historic streamflows are adjusted for effects of new groundwater uses and mitigation activities *as though* the uses and mitigation activities were in place, fully developed and fully realized, beginning in October 1965.

The effects of groundwater withdrawals and mitigation activities are measured by the percent of time flows exceed in-streamflow requirements, monthly and annually. As an example, Tables 3 and 4 show the baseline condition for the amount of time the scenic waterway flows are met in the Deschutes River below Pelton Dam. Examples of the impacts of various mitigation activities and groundwater allocations on streamflows in the Deschutes River above and below Billy Chinook are given in Appendices A and B.

Mitigation (Credits)

Mitigation activities are expected to offset the effects of the new allocations of groundwater on surface water. Mitigation is also provided as an option to existing ground water rights conditioned for regulation of scenic waterway flows to avoid possible regulation. In the real world, groundwater use will be linked to specific mitigation activities. For purposes of the model, however, mitigation activities and groundwater use are considered as independent of one another with mitigation activities generating credits and groundwater use generating debits.

Four types of mitigation are considered: 1) leases and transfers, 2) conserved water, 3) aquifer storage, and 4) allocation of existing, but previously unallocated storage to in-stream. Only leases and transfers of existing allocations (Case 1) may be considered to be ‘drop for drop’ mitigation, offsetting entirely the effects of the associated groundwater use. The other mitigation activities increase consumptive use overall in the basin.

Mitigation activities affect streamflow both above and below an area of groundwater discharge or zone of impact. All four cases of mitigation activities either modify existing diversions from surface flow or create new diversions. These additions to or subtractions from streamflow affect all stream reaches downstream whether above or below the area of discharge.

All of the mitigation activities except case 4 (allocation of existing, but previously unallocated storage) also affect groundwater discharge. These effects are realized only downstream of the affected zones of impact.

Each of the mitigation activities is discussed in detail in Appendix A. Both the conceptual model and the numerical model for each case are discussed. An example calculation is also described for each case.

Groundwater Withdrawals (Debits)

The impacts of groundwater withdrawals are simply accounted for in the model. They are debited from streamflow downstream from the zone of impact. Although the withdrawals likely vary seasonally, we assume the variation is completely attenuated by passage through the affected groundwater system. In the model, then, the impacts are uniformly distributed over the year. Upstream of the zone of impact, groundwater withdrawals have no effect on streamflow. Groundwater withdrawals are discussed in detail in Appendix B. Both the conceptual model and the numerical model are discussed. An example calculation is described.

Groundwater Rights with the 7J Condition

Between 1995 and 2000, 193 groundwater rights were issued with a condition allowing regulation if the use was found to cause a measurable reduction in streamflow. The Department commonly refers to this condition as the 7J condition. Measurable reduction is defined by the Scenic Waterway Act as a reduction in streamflows within the scenic waterway in excess of one percent of the average daily flows or one cubic foot per second, whichever is less. In the Deschutes basin, the threshold is one cubic foot per second in all cases.

In 2000, a study of groundwater in the Deschutes basin, conducted jointly by the USGS and the OWRD (Gannet et al., 2000), concluded that there is a preponderance of evidence to support a finding that groundwater use could cause a measurable reduction in scenic waterway flows. Water rights with the 7J condition are now subject to possible regulation. However, pursuant to the new Deschutes Ground Water Mitigation rules, these ground water right holders have the option of providing mitigation to avoid any future regulation.

Water rights with the 7J condition are not accounted for in the model as they are subject to regulation. If the permit holders obtain mitigation credits to offset their water use, the rights will not be subject to regulation. If mitigation is acquired for any of these rights, the water right and the new mitigation will be entered into the accounting.

Assumptions of the Model

A number of assumptions are made related to model development and implementation.

The first of these assumptions concerns groundwater recharge and discharge. For purposes of this model, water is added to the regional or to a local groundwater system by way of return flows. Water is subtracted by way of groundwater withdrawals. In either case, the effects on streamflow of these additions or the subtractions occur at the Zone of Impact associated with the groundwater system. Although the additions and subtractions most likely vary seasonally, we assume that this seasonality is completely attenuated by passage through the groundwater system, that is, the effects on discharge at the Zone of Impact are distributed uniformly in time.

We make two assumptions about the impact of Lake Billy Chinook on flows in the lower Deschutes River. First, we assume that mitigation activities do not impact the operation of Round Butte and Pelton dams. Changes in streamflow upstream of Billy Chinook are passed through to the Deschutes River below Pelton dam. Second, we assume future changes in operation of the Round Butte and Pelton dams are independent of any changes in streamflow due to mitigation activities. These changes will be modeled separately from and will be added to changes from the mitigation activities.

Finally, we assume steady state conditions, that mitigation activities and groundwater withdrawals are fully developed and that their effects downstream are fully realized.

A number of other assumptions are made specific to the type of mitigation involved. These assumptions are made for their respective cases as the cases are presented in Appendix A.

Shortcomings of the Model

The model has at least four shortcomings. First, the model does not account for streamflow travel times and attenuation of flows. This shortcoming would affect streamflows from water leased or transferred in-stream if the releases were variable, e.g., proportional to existing streamflow. However, in-stream transfers will be constant over long periods. For example, an in-stream transfer might be set for 5 cfs from April to June, 3 cfs from July to August and 2 cfs in September and October. When streamflows remain constant, the effects of travel time and attenuation are small.

Second, the model does not account for storage effects due to Lake Billy Chinook. The model assumes that changes in streamflow due to leases or transfers of water in-stream or due to new diversions for aquifer storage are simply passed through Lake Billy Chinook without affecting operation of the reservoir.

This assumption does not claim that the reservoir has no effect on streamflows passing through it; the reservoir, in fact, *does* affect flows. These effects are accounted for in the streamflow record below the reservoir. The assumption only claims that streamflow changes due to mitigation activities upstream of the reservoir would not have caused a change in reservoir operation.

Apart from its operation, the reservoir could attenuate changes in streamflow simply because it's a wide spot in the river. As already noted, however, in-stream releases due to leases and transfers will be constant for long periods and attenuation should not be a factor. On the other hand, diversions for aquifer storage are not likely to be uniform. The model will not account for smoothing of these decreases in streamflow.

Third, the model uses a uniform time series for groundwater discharge. The actual discharges from groundwater to surface water probably have seasonal and annual variations. If and when reasonable descriptions of these variations can be developed, they will be incorporated into the model.

Fourth, not every in-stream water right could be evaluated for impacts due to mitigation activities. Only those in-stream water right reaches with a gaging station in operation from 1966 to 1995 were candidates for evaluation.

References

Gannett, M.W., Lite, K.E., Morgan, D.S., and Collins, C.A., 2000, Ground-water hydrology of the upper Deschutes basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 00-4162, 77 p.