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To: Bob Loucks

From: Carter Borden

Subject: Evaluation of Irrigation Diversion Operation along the Lemhi River, Idaho

Introduction

It is DHI's understanding that diversion of water for irrigation from the Lemhi River is subject to water rights and associated priority dates. The priority date dictates which water rights are filled when stream flow is limited. Older (senior) water rights have priority over more recent (junior) rights. In other words, if there is only enough water in the river to serve water rights with a 1940 or earlier priority date, water rights associated with priority dates more recent than 1940 are not filled. When water in the river is limited, the Lemhi River is operated under restrictions administered by the Lemhi River Watermaster to ensure that irrigation diversions with senior water rights are filled before diversions with junior water rights.

This study was developed to evaluate whether the diversion of water for irrigation causes any parts of the Lemhi River to go dry. This objective was addressed by evaluating the effects of regulating irrigation diversions by water right priority dates on stream flow along the Lemhi River from McFarland Campground to the confluence of the Lemhi and Salmon Rivers near Salmon, Idaho. The study was requested by Bob Loucks, Idaho Department of Water Resources (IDWR) and local stakeholder in the Lemhi River Basin, to illustrate how priority dates associated with irrigation diversions generally influence stream flow in the Lemhi River. IDWR and US Bureau of Reclamation staff reviewed this report before release.

The study was completed by using the existing Lemhi River MIKE Basin Model (LRMBM) (DHI 2003). The existing LRMBM represents precipitation, tributary inflow, and groundwater upwelling by "reach gains" as described in the documentation report. The existing LRMBM was constructed from data available during discrete time periods between June 1999, and October 2001. Lemhi River inflows and reach gains in the LRMBM were varied in that model to represent changes in precipitation, tributary inflow, and groundwater upwelling that occurred during those time periods.

Methods

The existing LRMBM did not account for water right priority dates or the influence of regulation on stream flow in the Lemhi River. Therefore, the existing LBMBM was configured to evaluate the amount of stream flow that would be expected to be present in different reaches of the Lemhi River when water is unregulated and all water right demands are attempted to be met, and when available inflows decrease and the system is correspondingly regulated by the watermaster for different levels of water right priority dates.

Three different approaches were taken to evaluate the effects of regulation on flows in the Lemhi River. In each case, the reach gains used in the LRMBM were held constant. In the first case reach gains were calculated to represent the lowest recorded stream flow conditions. These simulations are referred to in the remainder of this paper as the "Minimum Reach Gain Scenarios". The second case is a variation of the first. The second case used average stream flow conditions and is called the "Average Reach Gain Scenario". In the third case no reach gains were used in the model. These simulations are referred to in the remainder of this paper as "Zero Reach Gain Scenarios".

Some common elements were incorporated in the model analysis for all approaches described in this paper. All simulations were run on a daily time-step for a 4-month period with constant inflow, constant ET rate, and one of the six constant diversion rates (described below) for the duration of the simulation. For the Minimum and Zero Reach Gain simulations, the U.S. Bureau of Reclamation's McFarland Campground and Hayden Creek gages represented the water entering the model. For these simulations, a constant inflow representing the minimum 5-day average flow of the combined inflows from each gage for the period of the original simulation periods (June 16, 1999 to October 31, 2001) was used. Inflows of 67 and 15 cfs were input at the McFarland Campground and Hayden Creek gages, respectively, which occurred on September 16-20, 2000. The evapotranspiration rates from that same time period were used for these simulations. For the Average Reach Gain simulation, average Lemhi River inflow was calculated from data available between July 1 and October 31. Average Lemhi River inflow at McFarland Campground and Hayden Creek was 133 and 63 cfs, respectively. Average evapotranspiration rates for the July 1 to October 31 period were used. Results presented for all simulations were taken 3.5 months into the simulation period to account for irrigation water returning to the stream.

The quantity of water right diverted was assumed to be the maximum allowed in the water right. The full water right quantity was provided by Bob Loucks (2003) in an electronic file stating the water right number, priority date, and allowable quantity for each diversion. As restrictions due to priority dates were imposed, all diversions with a water right priority date junior to the restriction date were eliminated as described by the Lemhi River Watermaster (Sager, 2002).

Minimum Reach Gain Scenarios

The Lemhi River is a dynamic hydrologic system. Flows in the Lemhi River change continuously in response to changes in precipitation, runoff, subsurface flows, and irrigation. The existing LRMBM represented these dynamic influences as reach gains, and the majority of time it took to construct the existing LRMBM was devoted to construct the reach gains data set. However, the data needed to construct a dynamic reach gains data set to evaluate water right priority dates was not available. Even if the data were available, it would take several months to construct the data set. Therefore, it was decided to take a conservative approach and estimate reach gains for the model analysis conducted for this paper using available data for the lowest 5-day average flow obtained from the reach gain data set in the existing LRMBM. Reach gains were added to maintain a stream flow of 72 and 75 cfs at the site of the Lemhi and Barracks Lane

gaging stations, respectively. This approach resulted in a single reach gain data set that was held constant for all minimum reach gain scenario simulations.

Four simulations were configured using the minimum reach gains described above.

1. No restriction (430.6 cfs in demands), minimum reach gains included
2. 1940 restriction (384.1 cfs in demands), minimum reach gains included
3. 1915 restriction (370.8 cfs in demands), minimum reach gains included
4. 1914 restriction (347.1 cfs in demands), minimum reach gains included

Average Reach Gain Scenario

Reach gains were introduced to maintain average stream flows of 145 and 152 cfs at the site of the Lemhi and Barracks Lane gaging stations, respectively. These flows represent the average flow observed from July 1 to October 31 for the 1999 – 2001 irrigation season.

5. No restrictions (430.6 cfs in demands), average reach gains included

Zero Reach Gain Scenarios

As noted above, lack of available data precluded analysis of reach gains to correspond with the dynamic response of the Lemhi River system to different levels of regulation by water right priority dates. Another approach used to evaluate the response of the system to regulation was to eliminate reach gains entirely and use the model analysis to quantify the *relative change* in stream flow associated with different levels of regulation. For the following six scenarios, all reach gains at the USGS Lemhi and the USBR Barracks Lane gages were set to 0 cfs.

6. No restrictions (430.6 cfs in demands), no reach gains
7. 1940 restriction (384.1 cfs in demands), no reach gains
8. 1915 restriction (370.8 cfs in demands), no reach gains
9. 1900 restriction (294.5 cfs in demands), no reach gains
10. 1890 restriction (218.9 cfs in demands), no reach gains
11. 1887 restriction (171.1 cfs in demands), no reach gains

General Results for Minimum, Average, and Zero Reach Gain Scenarios

With minimum 5-day flows specified as Lemhi River inflows at the McFarland Campground and Hayden Creek gaging stations in all simulations, no unsatisfied demands or dewatered reaches occurred upstream from the L-21 diversion in any of the simulations for this study. Therefore, descriptions below and all included figures only refer to conditions downstream from the L-21 diversion.

Results for the Minimum Reach Gain Scenarios

The Lemhi River between the L-8 and L-7 diversions is the only reach that is simulated to go dry under conditions of minimum reach gains and minimum Lemhi River inflows at the McFarland Campground and Hayden Creek gaging stations. This dry reach is simulated to occur for unrestricted diversion conditions (figure 1) and regulation to 1940

(figure 2), and 1915 (figure 3) water right priority dates. However, no reach in the Lemhi River was simulated to go dry when the river was regulated to the 1914 water right priority date (figure 4). Simulations 1 through 4 also showed progressively greater stream flow in reaches downstream from the L-7 diversion as diversions were restricted to earlier water right priority dates. No further simulations were made to show conditions for regulation to priority dates earlier than 1914.

Results for the Average Reach Gain Scenario

No dry reaches were simulated in the Lemhi River, and all water rights were satisfied for average Lemhi River inflow and reach gain conditions (figure 5). Because there were no Lemhi River or delivery shortages, no additional simulations were made for any level of regulation with average conditions.

Results for the Zero Reach Gains Scenarios

Interpretation of results from the Zero Reach Gains Scenarios must be tempered by the knowledge that none of these scenarios included reach gains. Consequently, they illustrate the *relative* effect of regulation by water right dates on available stream flow. First, the initial reference point is established by representing the effects of all diversions *in the absence of reach gains*. Subsequent scenarios progressively eliminate diversions by earlier and earlier water right dates. Any of these scenarios then can be compared to the reference scenario or to each other to explore the magnitude of the influence of any particular scenario on the relative availability of stream flow in the Lemhi River.

With all of the diversions potentially active and capable of drawing a maximum of 430.6 cfs from the Lemhi River, scenario 1 indicates that without any reach gains the minimum inflows specified at the McFarland Campground and Hayden Creek gaging stations are not enough to meet most of the irrigation demands nor to sustain any stream flow in the Lemhi River in excess of irrigation diversions that can be satisfied (figure 5). Scenario 1 is the reference scenario.

As diversions were restricted in the remaining scenarios by specifying progressively earlier priority dates, the demands were reduced commensurately, satisfied irrigation nodes persisted further downstream, and there was a relative increase in Lemhi River stream flows from one scenario to the next (figure 6-10). For scenario 9, without any reach gains only the L-06 and L-07 diversions remained unsatisfied with an 1890 priority date restriction. These demands were satisfied, and flow remained in the river even without any specified reach gains when the 1887 priority right restriction (171.1 cfs in demands) was implemented (figure 10).

Discussion

Simulations developed for this study were intended to compare the relative influence of diversion operations by water right priority dates on stream flows in the Lemhi River. Scenarios 1-4 include conservative estimates for contributions from groundwater, tributary inflow, and precipitation; and scenario 5 includes average estimates for these features; but scenarios 6-11 only account for the quantity of water diverted and returned

to the stream and do not include the contributions from precipitation, tributary inflow, or groundwater gains and losses.

Directly simulating the discharge at any point in the Lemhi River is currently not possible with the LRMBM because of distance between stream gages, the limited data set upon which the model is calibrated, and the further refinements slated for development in 2004 (DHI 2003). Because the model does not directly account for tributary and groundwater inflow or precipitation, the distance between stream gages along the study reach renders the model incapable of providing exact stream discharge estimates at points between available gaging station (DHI 2003). In addition, in the LRMBM current status, the fractional loss to the intermediate groundwater fraction is also lost to the system. Even with these two limitations, the LRMBM can be used to evaluate trends in data associated with diversion operations. Current inclusion of a deep groundwater component associated with the diversion operations will be implemented in 2004, and the installation of additional gages is under consideration.

Summary and Conclusions

The LRMBM was used to estimate the influence of diversion operations by water right priority dates on Lemhi River stream flow. Three approaches were followed to explore these influences. In the first approach Lemhi River inflows and reach gains, which represented the contribution to stream flow from precipitation, tributary inflow, and groundwater upwelling, were set to the minimum 5-day average obtained from an earlier LRMBM analysis. The objective of this approach was to produce a quantitative estimate of stream flow in the Lemhi River using values that represented the driest short-term conditions for the period of record. Results from this analysis indicated that for unrestricted diversions and diversions regulated to 1940 and 1915 water right priority dates, only the reach between the L-8 and L-7 diversions went dry. No dry reaches in the Lemhi River were estimated when diversions were regulated to the 1914 water right priority date.

In the second approach minimum average Lemhi River inflows and reach gains were used. No Lemhi River reaches were simulated to go dry and all water rights were satisfied for average conditions.

In the third approach Lemhi River inflows were specified, but reach gains were set to zero. Results from this analysis illustrated relative differences in Lemhi River stream flow associated with regulating diversions to different water right priority dates. Results indicated that available stream flow increased as the river was regulated to progressively earlier water right priority dates.

Results from all approaches indicate that stream flow in the Lemhi River is influenced by irrigation diversions. Also, results indicate that the regulation of those diversions by water right priority date influences the magnitude of flow in different parts of the river. Furthermore, even with high levels of irrigation diversions, irrigation return flows maintain stream flow throughout most of the Lemhi River. For example, the LRMBM Minimum Reach Gain analysis illustrated that only one reach was estimated to go dry

until the river was regulated to the 1914 water right priority date. These results are fairly remarkable considering that *constant minimum* Lemhi River inflows and reach gains were specified for the *entire* 4-month duration of the LRMBM analysis. Actual Lemhi River inflows are naturally high during spring runoff and gradually diminish as the snowpack disappears whereupon inflows are sustained by baseflow conditions. Reach gains generally follow a similar pattern, but lag behind and are attenuated compared to the response of the stream. The 1997 USGS seepage run of the Lemhi River concluded that the Lemhi River is a gaining system for all but one reach around Barracks Lane (Donato,1998). Considering the natural hydrologic regimen, the LRMBM Minimum Reach Gain analysis used extremely conservative values for the magnitude of Lemhi River inflows and reach gains. Consequently, the configuration of the LRMBM in the minimum Reach Gain analysis implies that actual Lemhi River stream flow conditions would not be expected to be less than indicated by the results. Moreover, actual Lemhi River stream flows would be expected to be greater than those indicated in the results.

The Average Reach Gain simulation illustrates that no Lemhi River stream flow deficiencies or water right shortages would be expected to occur for average stream flow conditions.

Representation of the hydrologic dynamics for Lemhi River inflows and reach gains are instrumental to obtain reliable LRMBM estimates. Unfortunately, the hydrologic information needed to develop dynamic reach gain data sets was not available for the purposes of this paper. Additional data and analysis is needed to better represent these contributions in the LRMBM.

References

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Donato, M. M. (1998). Surface-Water/Ground-Water Relations in the Lemhi River Basin, East-Central Idaho, U.S. Geological Survey**:** 20.

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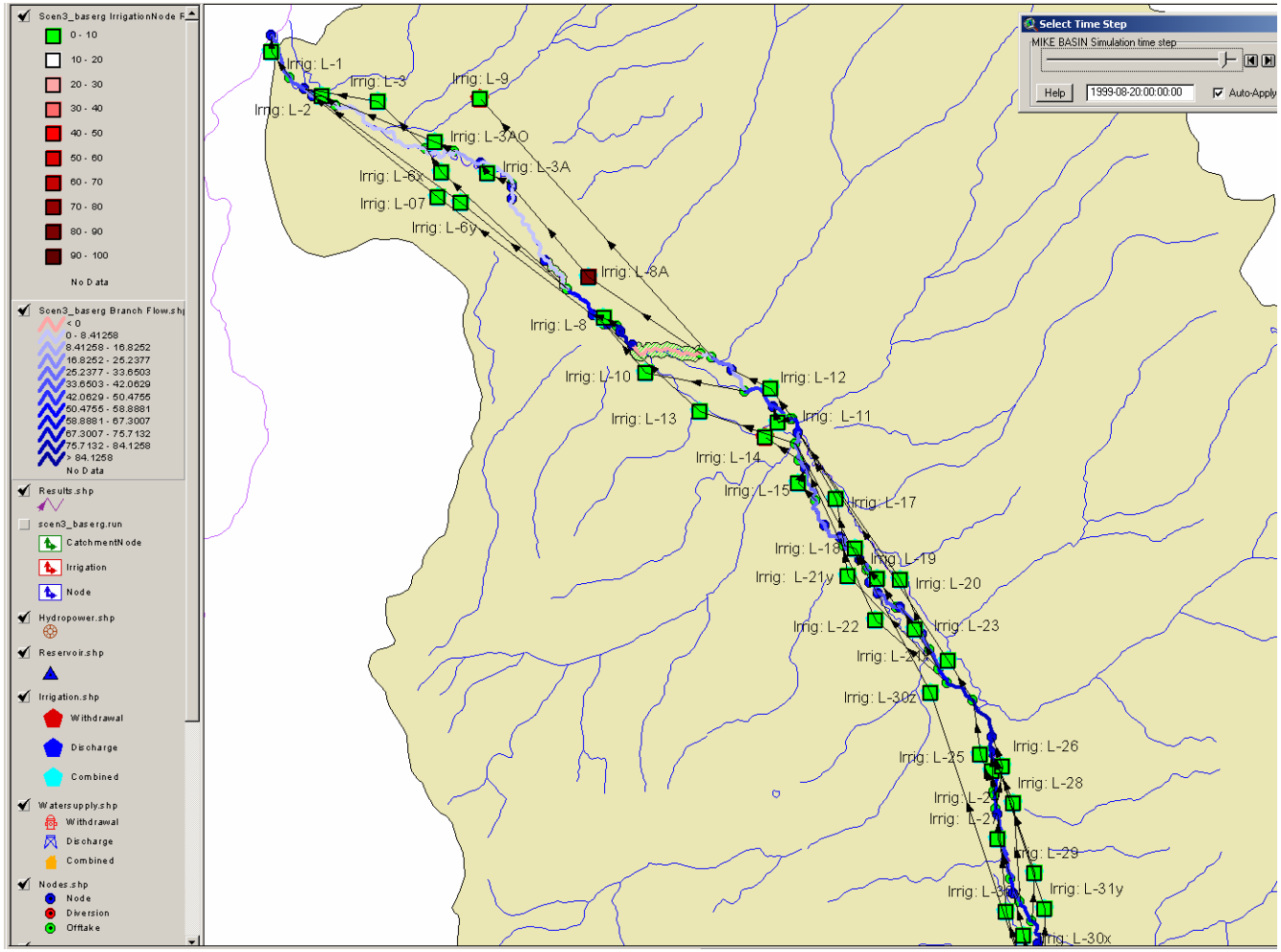

Figure 1. Scenario 1 – No priority date restriction and reach gains. Squares represent irrigated areas associated with diversions. Color of the square represents the relative amount of water received by an irrigated area. Green is satisfied and red is deficient (depth of red increasingly unsatisfied demand). For the Lemhi River, the deeper the blue, the greater the flow in the river. Pink river segment denote zero flow.

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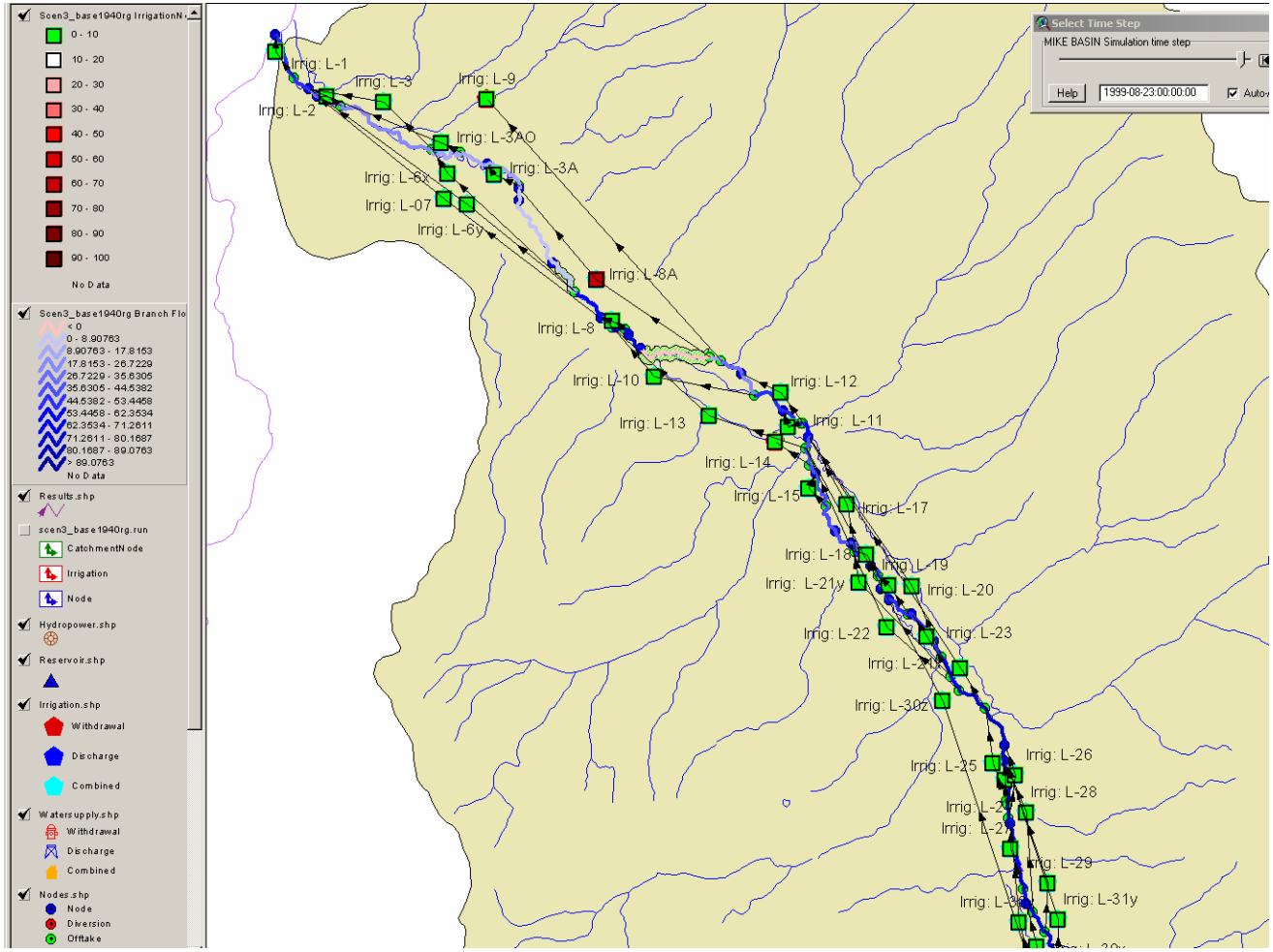

Figure 2. Scenario 2 - 1940 date restriction and reach gains. Squares represent irrigated areas associated with diversions. Color of the square represents the relative amount of water received by an irrigated area. Green is satisfied and red is deficient (depth of red increasingly unsatisfied demand). For the Lemhi River, the deeper the blue, the greater the flow in the river. Pink river segment denote zero flow.

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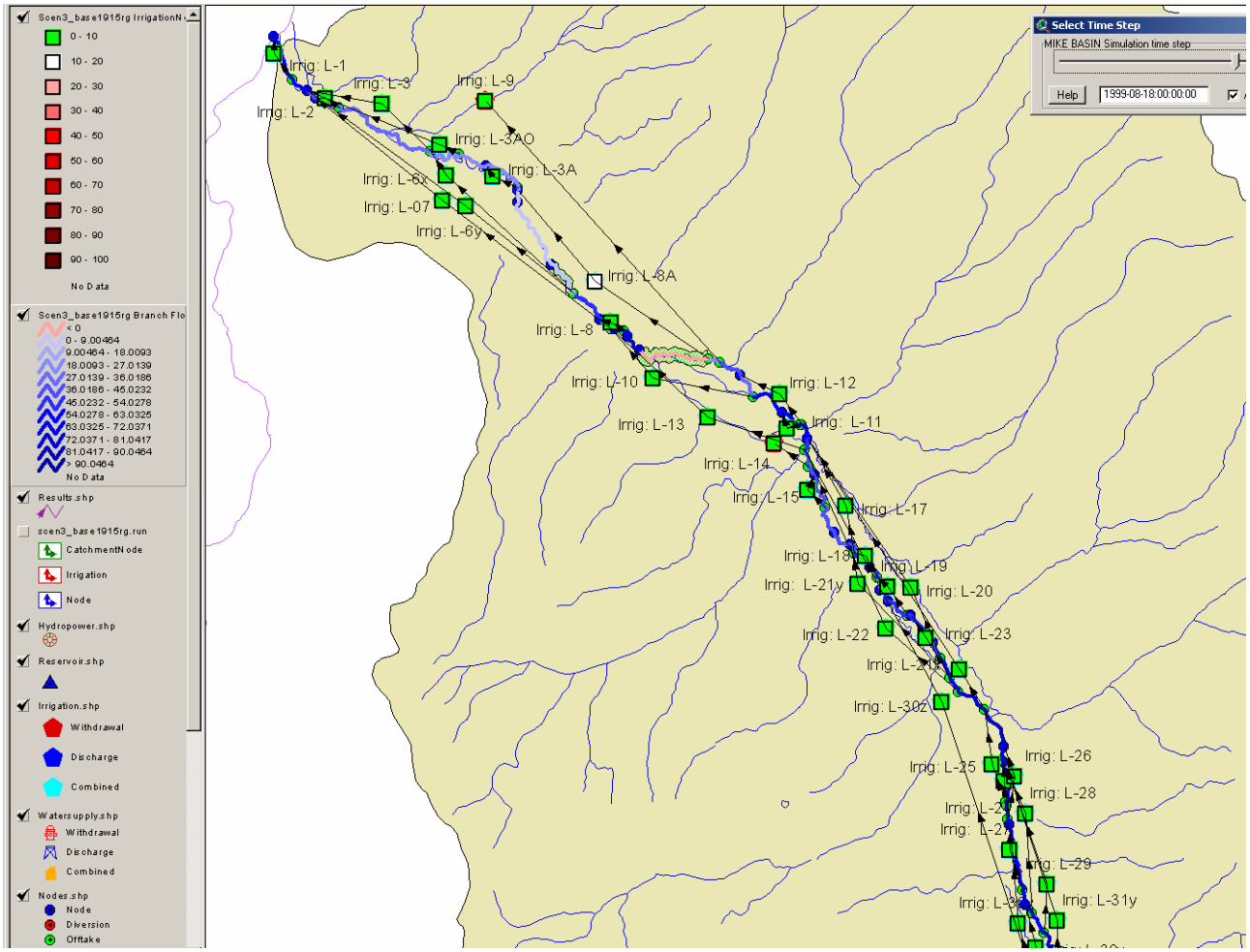

Figure 3. Scenario 3- 1915 date restriction and reach gains. Squares represent irrigated areas associated with diversions. Color of the square represents the relative amount of water received by an irrigated area. Green is satisfied and red is deficient (depth of red increasingly unsatisfied demand). For the Lemhi River, the deeper the blue, the greater the flow in the river. Pink river segment denote zero flow.

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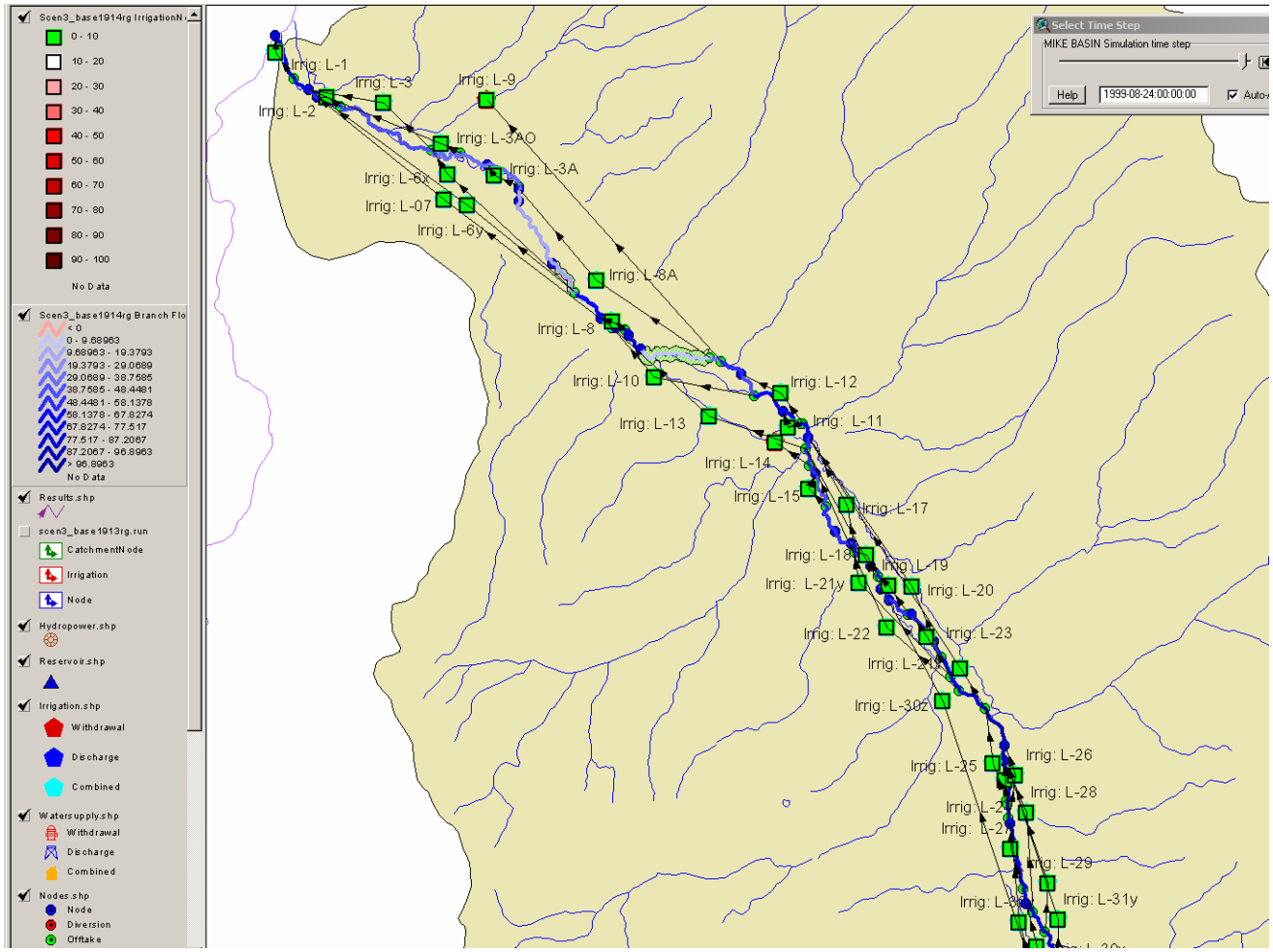

Figure 4. Scenario 4- 1914 date restriction and reach gains. Squares represent irrigated areas associated with diversions. Color of the square represents the relative amount of water received by an irrigated area. Green is satisfied and red is deficient (depth of red increasingly unsatisfied demand). For the Lemhi River, the deeper the blue, the greater the flow in the river. Pink river segment denote zero flow.

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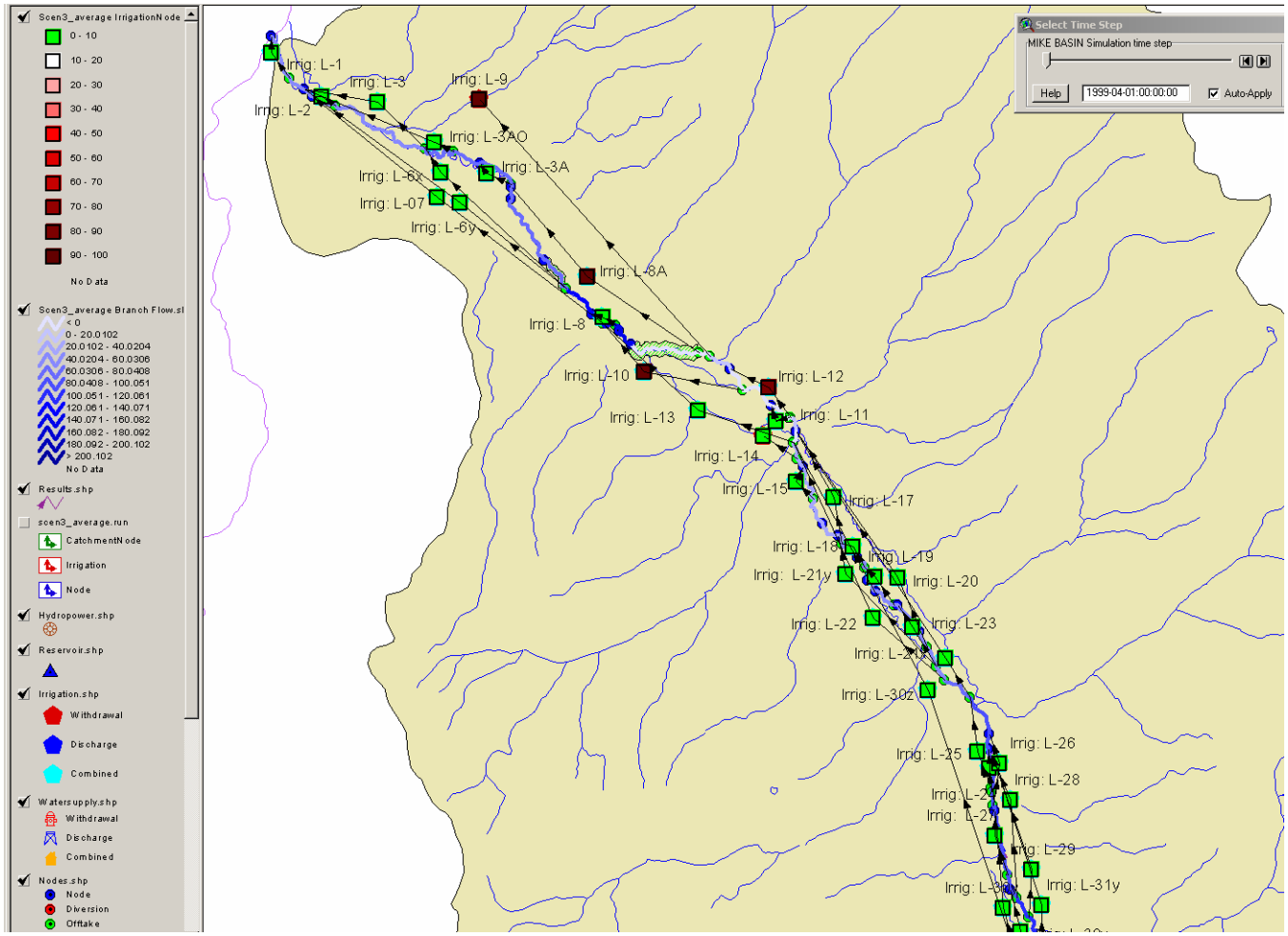

Figure 5. Scenario 5 – No priority date restriction and reach gains. Squares represent irrigated areas associated with diversions. Color of the square represents the relative amount of water received by an irrigated area. Green is satisfied and red is deficient (depth of red increasingly unsatisfied demand). For the Lemhi River, the deeper the blue, the greater the flow in the river. Pink river segment denote zero flow.

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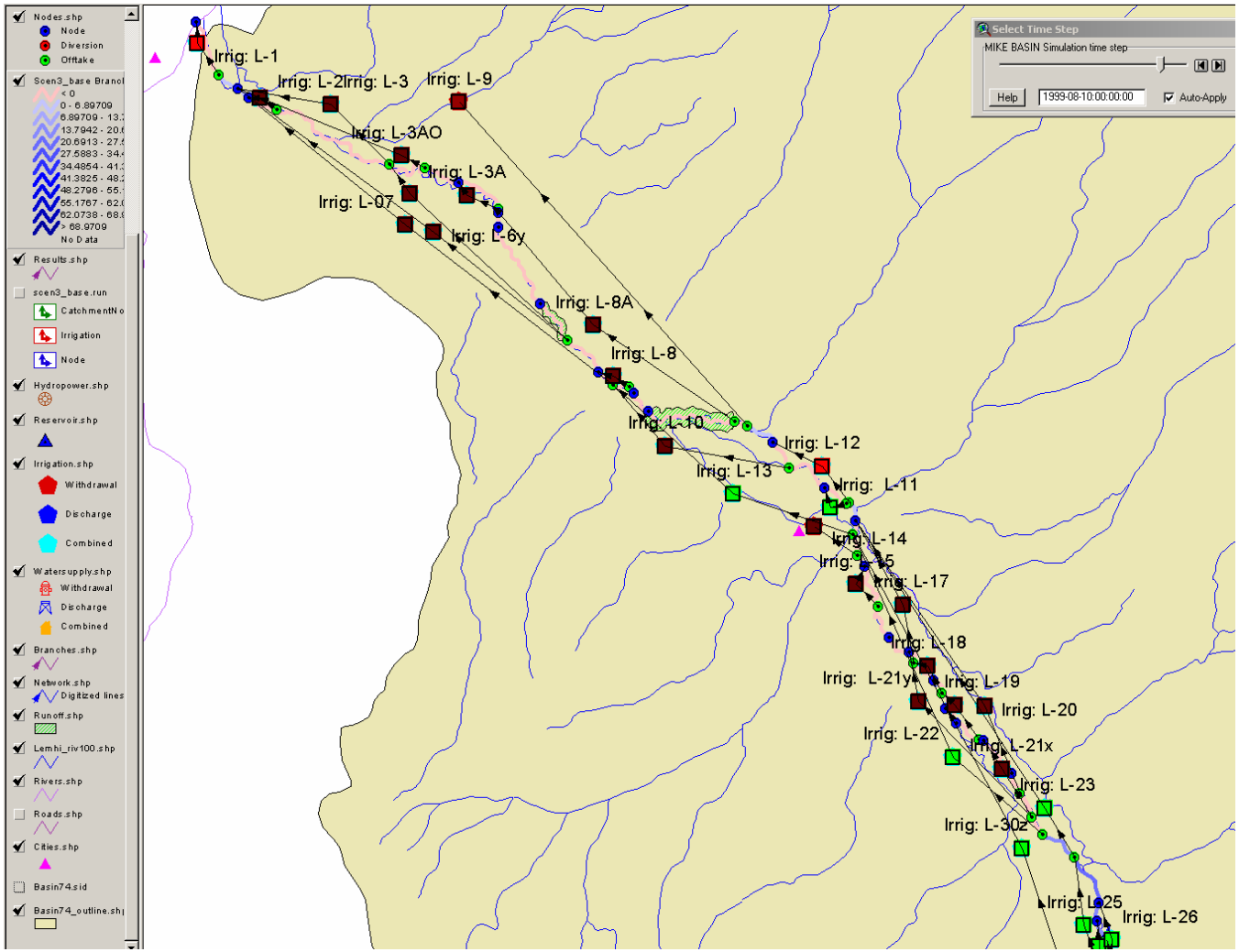

Figure 6. Scenario 6 – No restriction and no reach gains. Squares represent irrigated areas associated with diversions. Color of the square represents the relative amount of water received by an irrigated area. Green is satisfied and red is deficient (depth of red increasingly unsatisfied demand). For the Lemhi River, the deeper the blue, the greater the relative flow in the river. Pink river segment denote zero flow.

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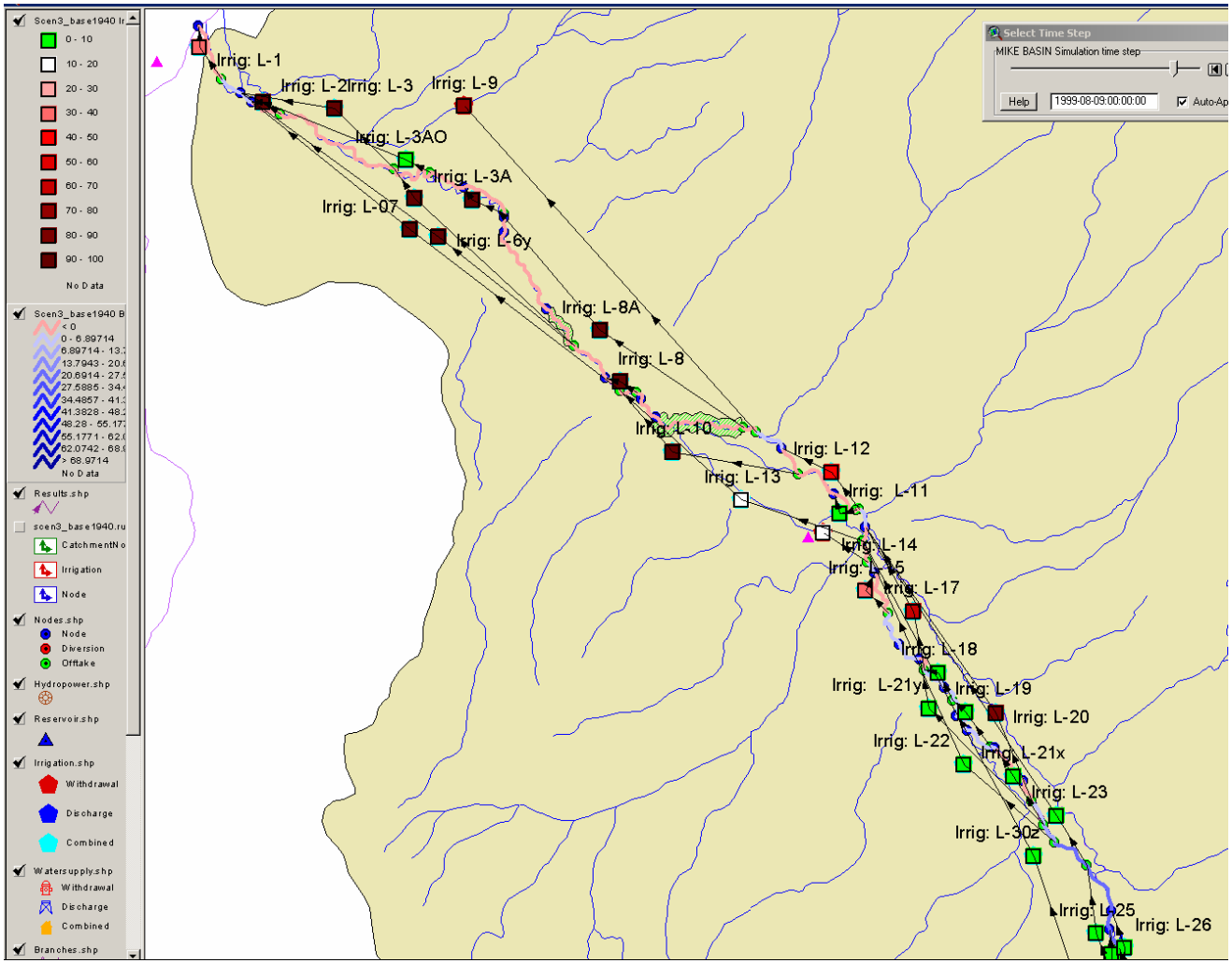

Figure 7. Scenario 7 – 1940 priority date restriction and no reach gains. Squares represent irrigated areas associated with diversions. Color of the square represents the relative amount of water received by an irrigated area. Green is satisfied and red is deficient (depth of red increasingly unsatisfied demand). For the Lemhi River, the deeper the blue, the greater the relative flow in the river. Pink river segment denote zero flow.

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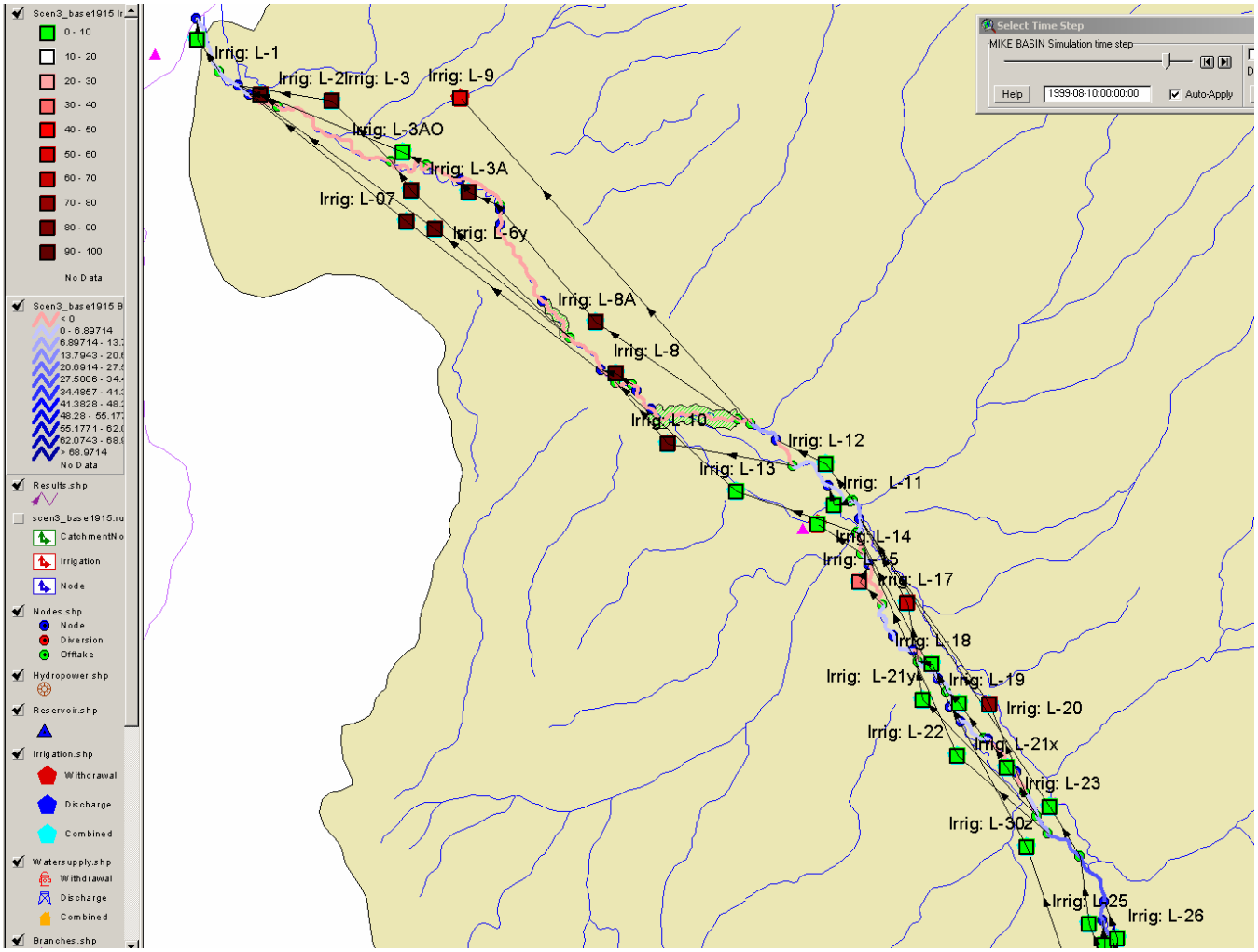

Figure 8. Scenario 8 – 1915 priority date restriction and no reach gains. Squares represent irrigated areas associated with diversions. Color of the square represents the relative amount of water received by an irrigated area. Green is satisfied and red is deficient (depth of red increasingly unsatisfied demand). For the Lemhi River, the deeper the blue, the greater the relative flow in the river. Pink river segment denote zero flow.

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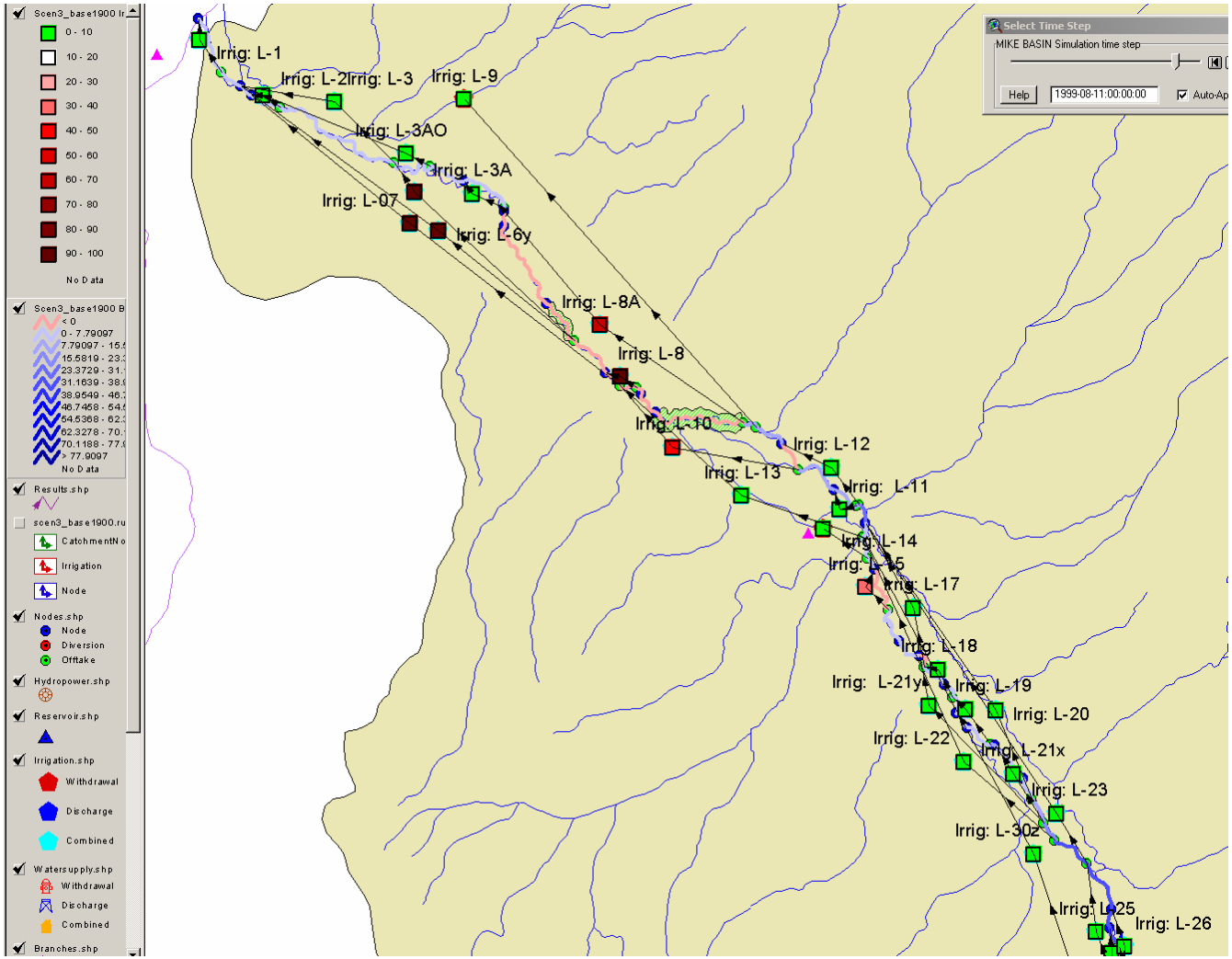

Figure 9. Scenario 9 – 1900 priority date restriction and no reach gains. Squares represent irrigated areas associated with diversions. Color of the square represents the relative amount of water received by an irrigated area. Green is satisfied and red is deficient (depth of red increasingly unsatisfied demand). For the Lemhi River, the deeper the blue, the greater the relative flow in the river. Pink river segment denote zero flow.

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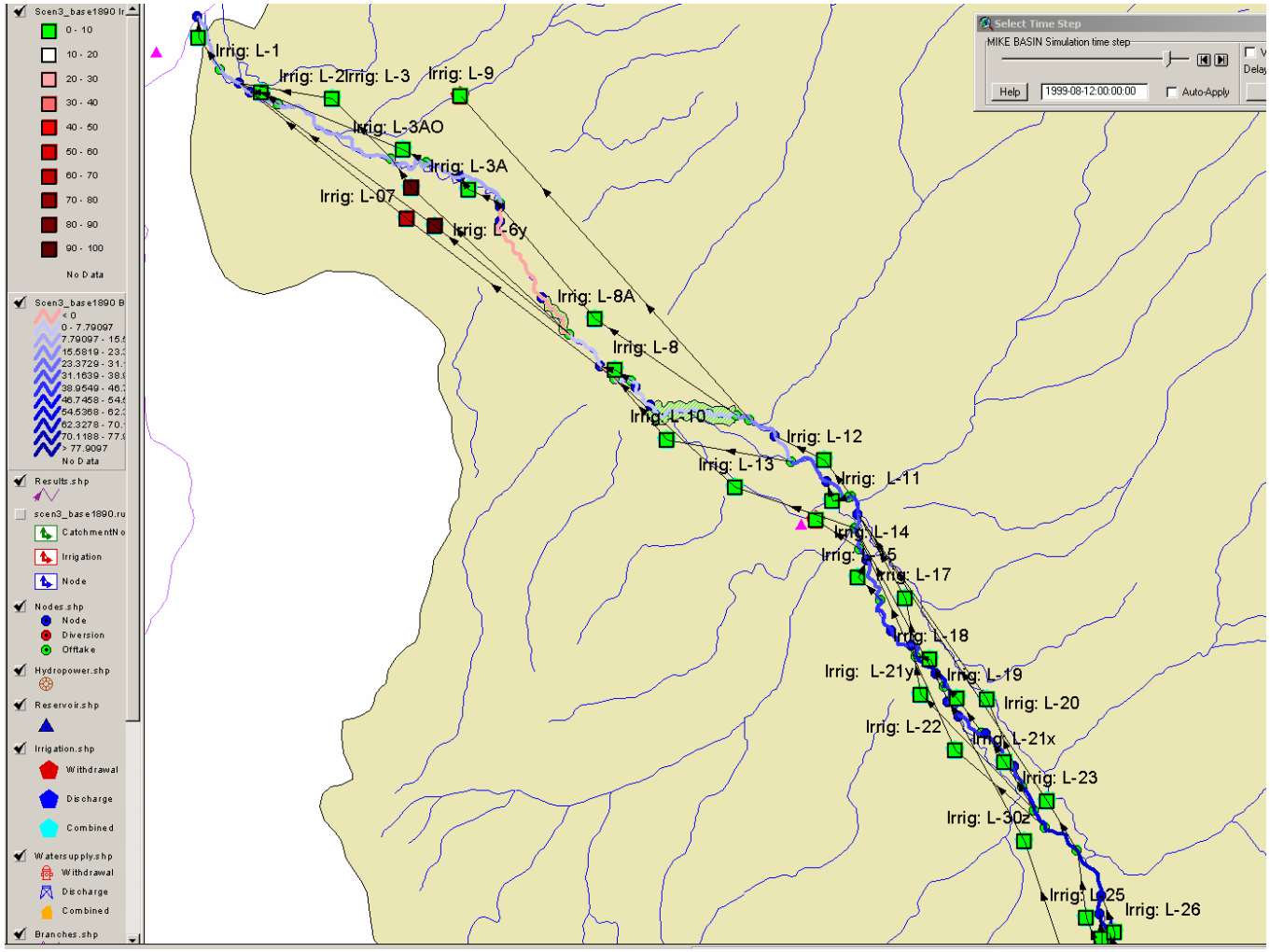

Figure 10. Scenario 10 – 1890 priority date restriction and no reach gains. Squares represent irrigated areas associated with diversions. Color of the square represents the relative amount of water received by an irrigated area. Green is satisfied and red is deficient (depth of red increasingly unsatisfied demand). For the Lemhi River, the deeper the blue, the greater the relative flow in the river. Pink river segment denote zero flow.

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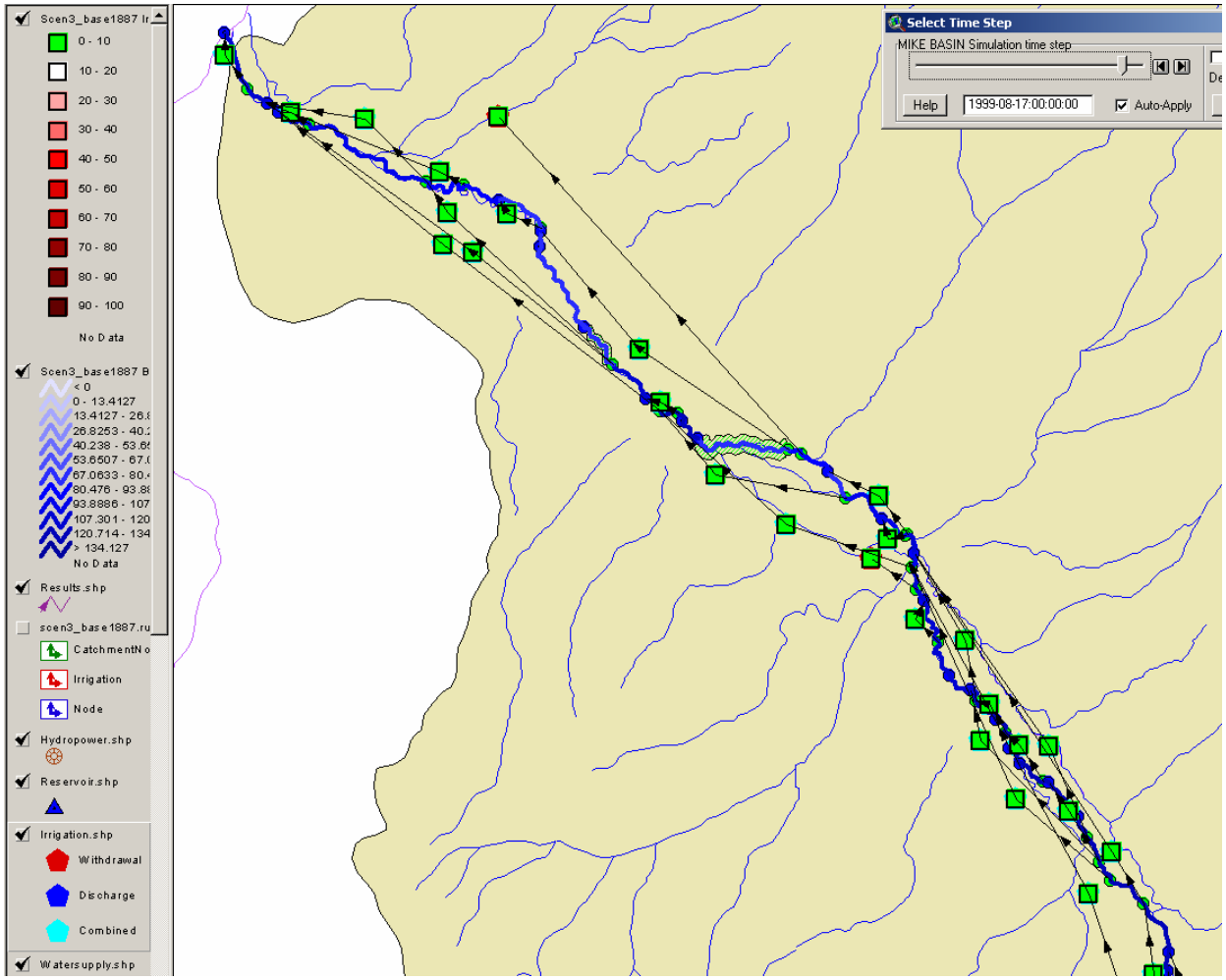

Figure 11. Scenario 11 – 1887 date restriction and no reach gains. Squares represent irrigated areas associated with diversions. Color of the square represents the relative amount of water received by an irrigated area. Green is satisfied and red is deficient (depth of red increasingly unsatisfied demand). For the Lemhi River, the deeper the blue, the greater the relative flow in the river. Pink river segment denote zero flow.