THE EFFECT OF DAM REMOVAL ON INFILTRATION TO THE SHALLOW WATER TABLE BENEATH SHIP CREEK

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1.0 Introduction

Shaw Environmental, Inc. supported Inter-Fluve, Inc. and the Alaska Department of Fish and Game on a project to improve fish passage along Ship Creek, near Anchorage, Alaska. Two sites are being considered for improvement, one near Fort (Ft.) Richardson, Alaska, and one near Elmendorf Air Force Base (AFB), Alaska. Both sites contain sheet pile dams of different sizes; removal of the dams is being considered as one alternative for improving fish passage along Ship Creek.

This report focuses on the use of simple numerical methods to evaluate the hydraulic impact on groundwater beneath each dam 1) when the dams are present and 2) after they have been removed. Hence two separate models were constructed, one for the reach near Ft. Richardson and one the reach near Elmendorf AFB.

2.0 Modflow

Groundwater flow at the site was modeled using finite-difference methods and the U.S. Geological Survey flow code, Modflow (McDonald and Harbaugh, 1989). Ground Water Vistas was used as a graphical user interface. There is little hydrogeologic data available for either site so relatively simple models were constructed. Both were assumed to be steady state and generally used average annual data for hydraulic parameters.

Site specific model grids were developed for Ft. Richardson and Elmendorf AFB and are described below.

3.0 Calibration

Normally, a flow model is calibrated to site specific hydraulic conditions. Calibration can be defined as “finding a set of parameters, boundary conditions, and stresses that produce simulated heads and fluxes that match field-measured values within a pre-established range of error” (Anderson and Woessner, 1992). Calibration procedures typically follow the practice of adjusting zones or specific values of hydraulic conductivity, recharge, or boundary heads to obtain an acceptable match in groundwater levels at specified target wells. For this project, neither model was calibrated in the traditional sense because of the lack of site-specific hydraulic conductivity and groundwater level data. For example, no hydraulic conductivity values are available for either site as slug tests or aquifer tests have not been performed. Shannon and Wilson (2005) performed specific capacity tests on Wells 4 and 5 at Elmendorf; they report transmissivities of about 15,000 gallons per day per foot. Assuming an aquifer thickness of

50 ft, this corresponds to a hydraulic conductivity of about 40 ft per day. Data from Ft. Richardson wells (U.S. Army, 2005) report transmissivities on the order of 14,000 gallons per day per ft, or 280 ft per day. Well logs from both sites indicate the wells are screened roughly 150 ft below ground surface and in a what is probably a confined aquifer; while this depth is greater than what we would expect to see impacted by changes in infiltration from Ship Creek, overall geologic conditions at both sites are still best represented by very permeable glacial fluvial deposits (Shannon and Wilson, 2005; U.S. Army, 2005; Hunter et al., 2000; Freethey, 1975). Data from well logs suggest the 50-75 ft directly beneath Ship Creek is primarily comprised of high-conductivity sands and gravels with occasional interbedded silts.

4.0 Ft. Richardson

Ft. Richardson is the most upstream dam site and is approximately six miles northeast of downtown Anchorage. The study area is adjacent to the fish hatchery (Figure 1); Ship Creek flows in a general southeast-to-northwest direction. The creek varies in width from about 100 ft directly behind the dam, to 40 to 60 ft upstream and downstream. The depth of the creek was assumed to vary from 4 ft behind the dam, to 3 ft elsewhere. Both the width and depth of Ship Creek is based on an annual average discharge of 150 cubic feet per second (Shannon and Wilson, 2005; U.S. Army, 2005). The discharge rate of 150 cubic feet per second was used by Inter-Fluve (Personal Communication, Mr. Dan Miller, 2006) to calculate the creek widths and depths reported above. All hydraulic and geologic data used in the model are summarized in Table 1.

4.1 Model Design

The model grid represented an area of 1,150 ft along the x-axis and 590 ft along the y-axis. Grid cells varied in size from 10 ft to 20 ft and were finer in the vicinity of the sheet pile dam (Figure 2). The grid was rotated 45 degrees to align the primary axis approximately with the assumed direction of groundwater flow. This allowed the use of constant head boundaries on the upgradient and downgradient ends of the model domain and no-flow boundaries along the parallel sides. Vertically, the model was split into three layers totaling 50 ft, although the multiple layers were only to ensure numerical stability in the model and did not imply a change in stratigraphy. The entire 50 ft was assumed to represent homogeneous and isotropic conditions and an unconfined aquifer.

Model layer one was 10 ft thick while layers two and three were each 20 ft thick.

Recharge to the shallow aquifer is unknown at the site, though it is assumed to be relatively high. Annual rainfall averages 15 inches per year, while average snowfall averages nearly 65 inches per year. For the Ft. Richardson model, recharge was set to 15 inches per year across the model

domain, except along Ship Creek proper. This may be on the low end but will give a conservative estimate of the effect on the water table. Recharge from precipitation was assumed to be zero along the creek channel.

Two basic scenarios were evaluated. In scenario one, the sheet pile dam was in place, penetrated to a depth of 10 ft, and was essentially impermeable. The creek varied in width from 40 to 50 ft and, except behind the dam, was three ft deep (Figure 2). The depth was increased to 4 ft in the roughly 50-ft-diameter ponded area directly behind the dam. In the second scenario, the dam was removed and the creek narrowed in the reach through the dam area (Figure 3). The creek was then set to a uniform depth of 3 ft throughout the model.

Infiltration from Ship Creek was simulated using Modflow's River Package. Input data, in addition to the creek depth, include the thickness of the creek bed material and the vertical hydraulic conductivity of that material. As all are unknown at Ft. Richardson, the bed material was assumed to be one ft thick with a vertical hydraulic conductivity of 1 ft per day. In the deeper, ponded area behind the dam, additional silt and finer-grained materials have likely settled out and the hydraulic conductivity was reduced to 0.5 ft per day.

Six artificial monitoring points were simulated along the creek channel to track the effect on the water table. Three were located upstream of the dam and three downstream and are shown on the figures as MP-1 through MP-6.

Constant head boundary conditions were established at the upgradient (southeast) and downgradient (northwest) ends of the model domain. Some depth to groundwater data were available nearby monitoring wells but without a well head elevation, an accurate comparison of model-predicted hydraulic heads to those measured in the field was not possible. Data from Shaw Environmental (Personal Communication, Ms. Laura Noland, 2006) indicate the depth to groundwater along the east side of Ship Creek is about 15 ft. Given that, and an estimated land surface elevation of 280 ft at the upgradient end of the model and 275 ft at the downgradient end, then approximate groundwater elevations can be derived. Hence the upgradient boundary head was set to an elevation of 275 ft; the downgradient boundary head was set to 261 ft.

4.2 Results

Because of uncertainty in aquifer properties, the model was run with different hydraulic conductivities varying from 50 ft per day to 300 ft per day, The results of the two basic scenarios (dam present or no dam present) are shown in Figures 4–11. Tables 2 through 5 list the predicted water table elevations at MP-1 through MP-6 and the difference when the dam is removed. The results can be summarized as follows:

- In every case, the water table declined when the dam was removed. This is due to the simple fact that less water is ponded; with less hydraulic head behind the dam, less infiltration occurs.
- The change was most noticeable just upstream and just downstream of the dam.
- The maximum decline in water table was about 1.8 ft and was predicted when the aquifer hydraulic conductivity is 100 ft per day (Table 3).

5.0 Elmendorf AFB

The Elmendorf AFB site is approximately 4 miles downstream of Ft. Richardson and roughly the same distance northeast of downtown Anchorage. The study area is adjacent to the fish hatchery and Ship Creek flows in a generally north to south direction (Figure 12). There are two sheet pile dams at this site and the creek varies in width from over 100 ft directly behind the upstream dam to 50-60 ft wide further upstream and downstream. The depth of the creek was assumed to vary from 5 ft in the ponded area behind the upstream dam, 9 ft behind the downstream dam, to as little as 2 ft elsewhere. Like at Ft. Richardson, both the width and depth of Ship Creek at Elmendorf AFB is based on an annual average discharge of 150 cubic feet per second (Shannon and Wilson, 2005; U.S. Army, 2005). The discharge rate of 150 cubic feet per second was used by Inter-Fluve (Personal Communication, Mr. Dan Miller, 2006) to determine the creek widths and depths reported above.

5.1 Model Design

The model grid represented an area of 540 ft along the x-axis and 810 ft along the y-axis and was similar to that used at Ft. Richardson. Grid cells varied in size from 10 ft to 20 ft and were finer in the vicinity of the sheet pile dam (Figure 13). The grid was aligned north-south in the assumed direction of groundwater flow to permit constant head boundaries on the upgradient and downgradient ends of the model domain and no-flow boundaries along the parallel sides. Vertically, the model was again split into three layers totaling 50 ft, although the multiple layers were only to ensure numerical stability in the model and did not imply a change in stratigraphy. The entire 50 ft was assumed to represent homogeneous and isotropic conditions and an unconfined aquifer.

As before, model layer one was 10 ft thick while layers two and three were each 20 ft thick.

Recharge to the shallow aquifer is unknown at the site, though it is assumed to be at least as high as at Ft. Richardson. Annual rainfall averages 16 inches per year, while average snowfall averages over 75 inches per year. For this site, recharge was set to 16 inches per year across the model domain, except along Ship Creek proper. Again, this may be on the low end of actual

recharge but will give a conservative estimate of the effect on the water table. Recharge from precipitation was assumed to be zero along the creek channel.

Two basic scenarios were evaluated. In scenario one, both sheet pile dams were in place, penetrated to a depth of 10 ft, and were essentially impermeable. The creek varied in width and, except behind the dams, was two ft deep (Figure 13). The depth was increased to 5 ft in the ponded area directly behind the dam upstream dam and to 9 ft in the area behind the downstream dam.

In the second scenario, both dams were removed and the creek narrowed in the reach through the dam area (Figure 14). The creek was then set to a uniform depth of 2 to 2.5 ft throughout the model.

Infiltration from Ship Creek was simulated using Modflow's River Package. Input data, in addition to the creek depth, include the thickness of the creek bed material and the vertical hydraulic conductivity of that material. Like at Ft. Richardson, all are unknown at the Elmendorf site. Therefore, the creek bed material was assumed to be one ft thick with a vertical hydraulic conductivity of 1 ft per day. In the deeper, ponded areas behind the upstream dam, additional silt and finer-grained materials have likely settled out and the hydraulic conductivity was reduced to 0.5 ft per day. In the area behind the downstream dam, the deeper pool is due to water rushing over the upstream dam and the creek velocity is probably relatively high. Therefore the creek bed hydraulic conductivity was not reduced in this zone and remained at one ft per day.

Seven artificial monitoring points were simulated along the creek channel to track the effect on the water table. Three were located upstream of the dams, three downstream, and one in between the two dams (Figure 13).

Constant head boundary conditions were established at the upgradient (northern) and downgradient (southern) ends of the model domain. No current depth to groundwater data were available for the Elmendorf site. Shannon and Wilson (2005) reported a static depth to water of about 39 ft upon completion of hatchery well #5, and 25 ft at hatchery well #4. However, both wells are screened at 140 to 150 ft below ground surface and these water levels are probably not representative of the shallow aquifer. However, in the absence of any other data, and assuming a ground surface elevation of approximately 100 ft at the upgradient end of the model, boundary conditions can be estimated. Therefore, the upgradient boundary head was set to an elevation of 75 ft and the downgradient boundary head was set to 73 ft.

The reader is reminded that there is uncertainty in these models resulting from the lack of site-specific hydrogeologic data. However, simply establishing an adequate hydraulic gradient,

whether it represents actual site conditions or not, is sufficient to examine the effect on infiltration from Ship Creek when the dams are removed.

5.2 Results

The Elmendorf model was run with hydraulic conductivities varying from 50 ft per day to 200 ft per day. The results of the two basic scenarios (dams present or dams absent) are shown in Figures 15–20. Tables 6 through 8 list the predicted water table elevations at MP-1 through MP-7 and the difference when the dam is removed. The results can be summarized as follows:

- In every case, the water table declined when the dams were removed. As at Ft. Richardson, this is due to the simple fact that less water is ponded; with less hydraulic head behind the dams, less infiltration occurs.
- The change was most noticeable just upstream, just downstream, and in between the two dams.
- The maximum decline in water table was about 16 ft and was predicted when the aquifer hydraulic conductivity is 100 ft per day (Table 7).

Note that a hydraulic conductivity of 300 ft per day was not simulated for Elmendorf AFB. This is because the change in water level when the dams were removed was negligible with a conductivity of 200 ft per day and there was no point in modeling the higher value.

6.0 Conclusions

Groundwater flow was simulated with simple, conservative models of the shallow aquifer underlying Ship Creek at Ft. Richardson and Elmendorf AFB. The effect on infiltration from Ship Creek to the water table was analyzed 1) with existing sheet pile dams in place and 2) with the dams removed. Model results indicate that the water table will drop at both sites and that the level is somewhat sensitive to the hydraulic conductivity of the aquifer material. For an average conductivity of 100 ft per day, the decline in water level averages 1.4 ft at Ft. Richardson. Under the same conditions at Elmendorf AFB, the water level declines an average of 3.6 ft. The difference is due to Ship Creek generally being wider and deeper at Elmendorf and therefore the model allowed more infiltration along this reach.

Uncertainty in the model could be reduced if site-specific hydrogeologic data were collected and used as input. This could include slug or aquifer tests to determine the hydraulic conductivity, and current static water levels from monitoring wells with surveyed measuring points.

Overall, these results suggest that removal of the sheet pile dams will have a minimal effect on the underlying water table. Moreover, given that a conservatively-low recharge rate was used at both sites, the actual change in water level may be even less.

7.0 References

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Shannon and Wilson, 2005, *Evaluation of Pumping Test and Water Quality Data, Elmendorf Fish Hatchery Wells, Anchorage, Alaska*, Letter report to Aarow Pump and Well Service, Shannon and Wilson, Inc., Anchorage Alaska.

U.S. Army, 2005, *Draft Aquifer Study, Fort Richardson, Alaska*, U.S. Army Garrison, Alaska.

Figures

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Figure 1
Ship Creek Near Fort Richardson

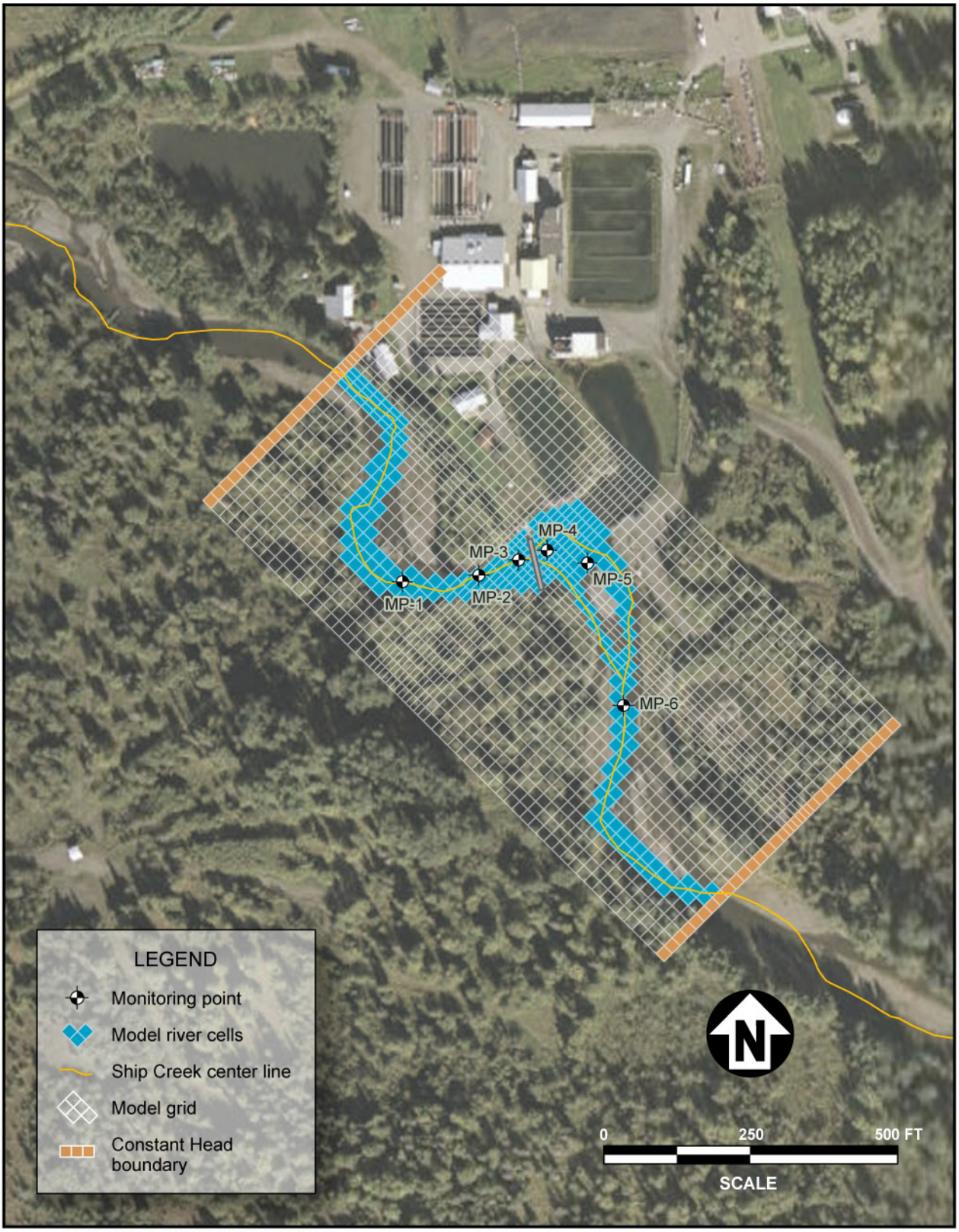

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Figure 2

Fort Richardson Model Domain, with Dam Present

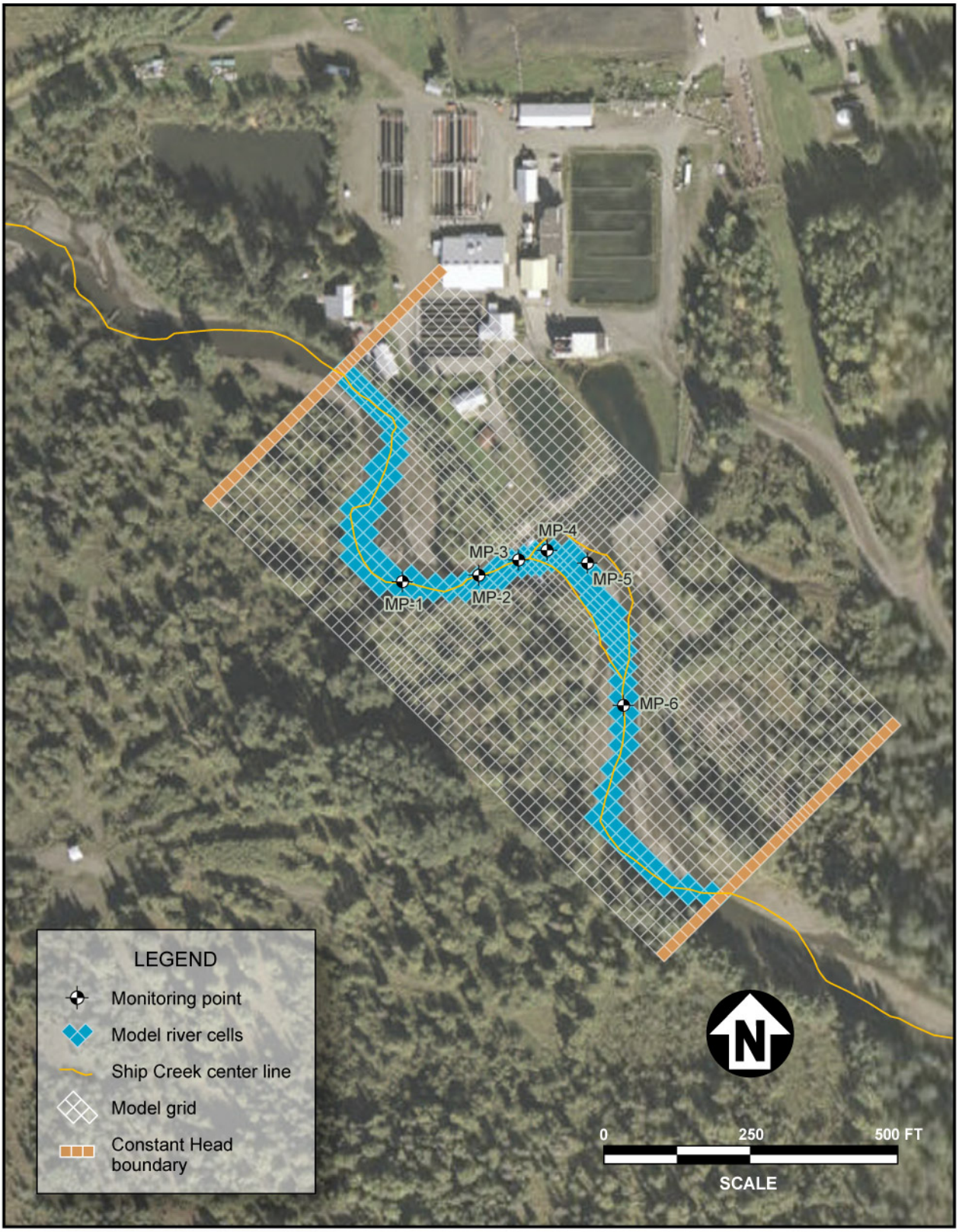

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Figure 3

Fort Richardson Model Domain, without Dam

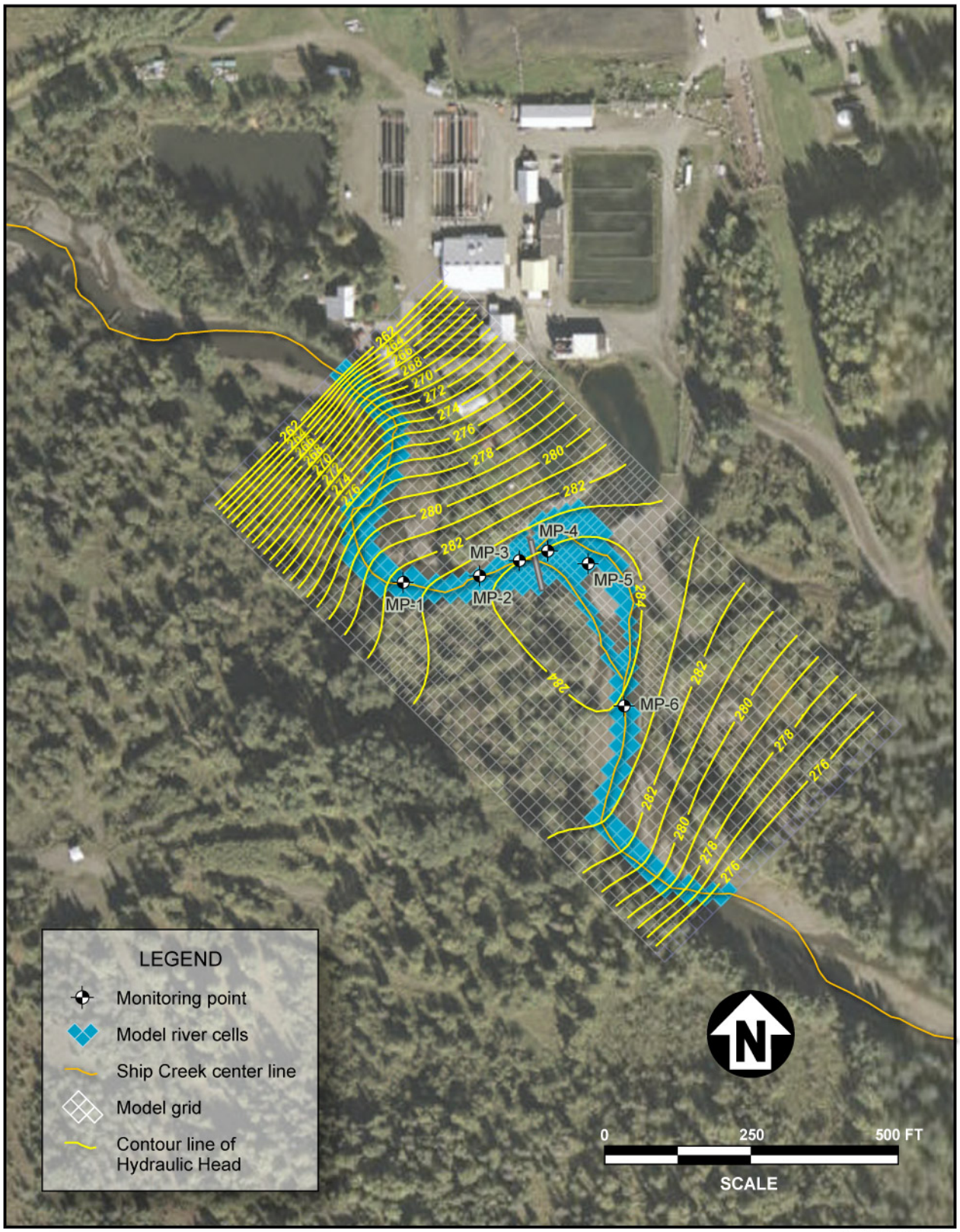

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Figure 4

Model-Predicted Hydraulic Head, K=50 ft/day, Dam Present

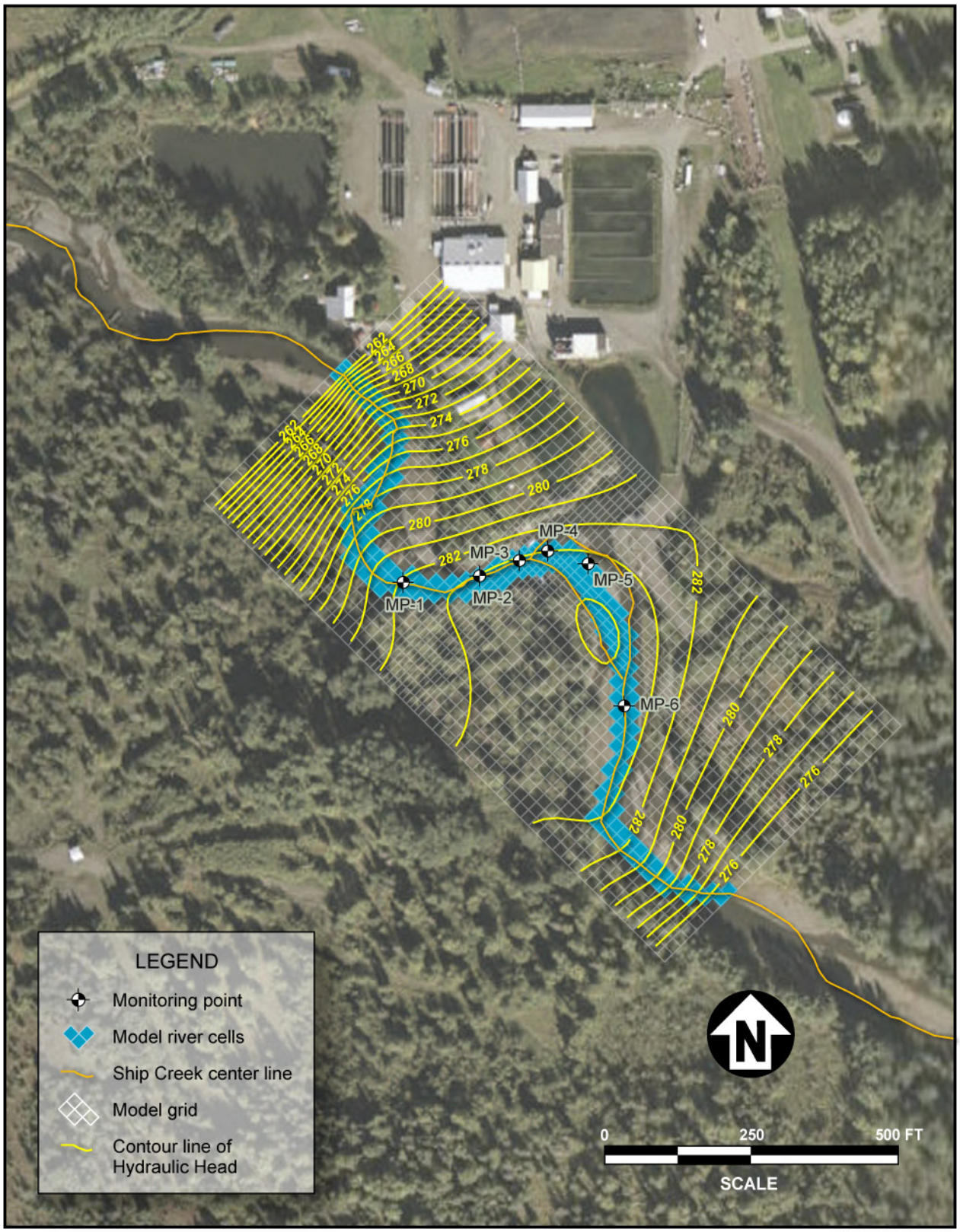

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Figure 5

Model-Predicted Hydraulic Head, K=50 ft/day, No Dam

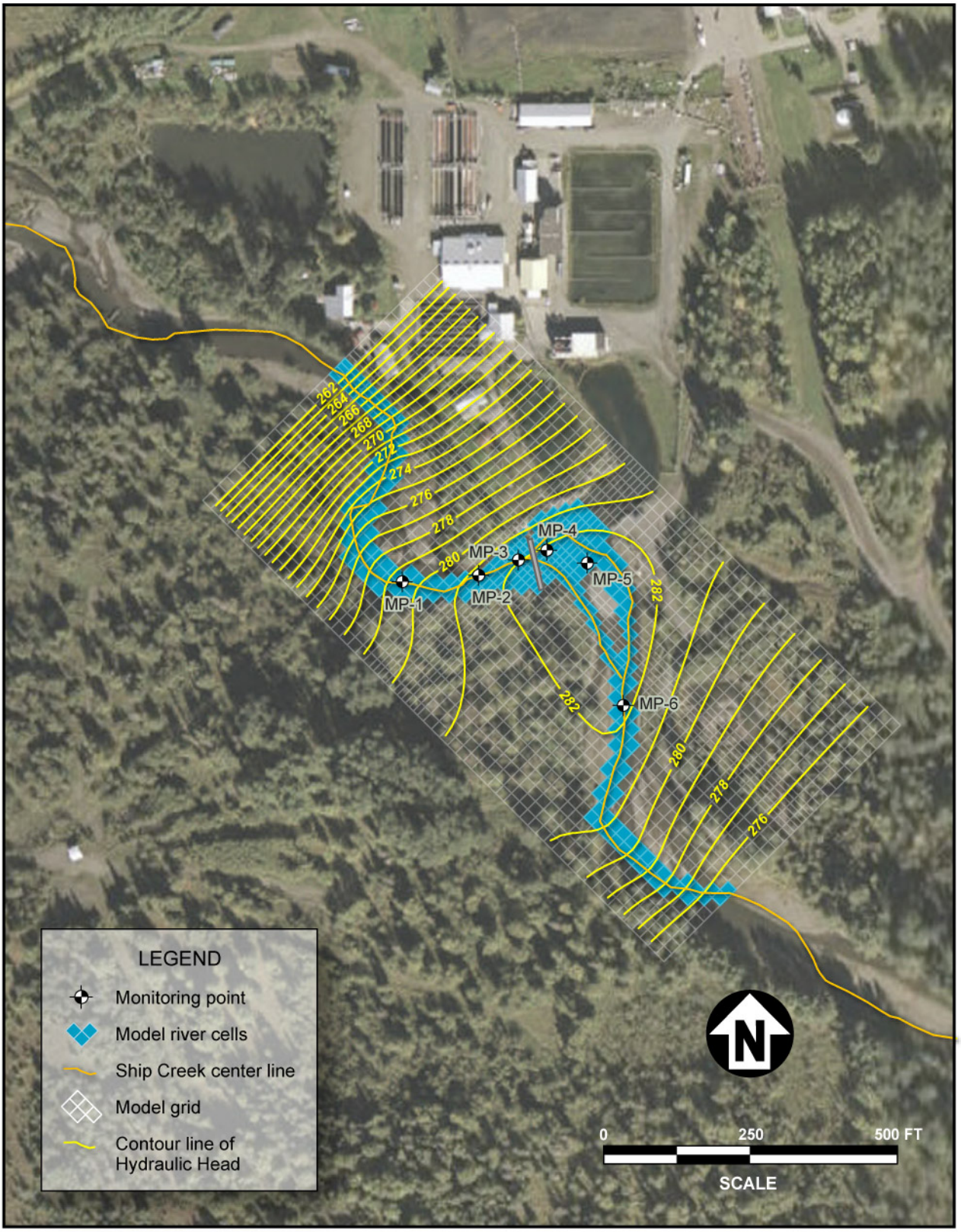

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Figure 6

Model-Predicted Hydraulic Head, K=100 ft/day, Dam Present

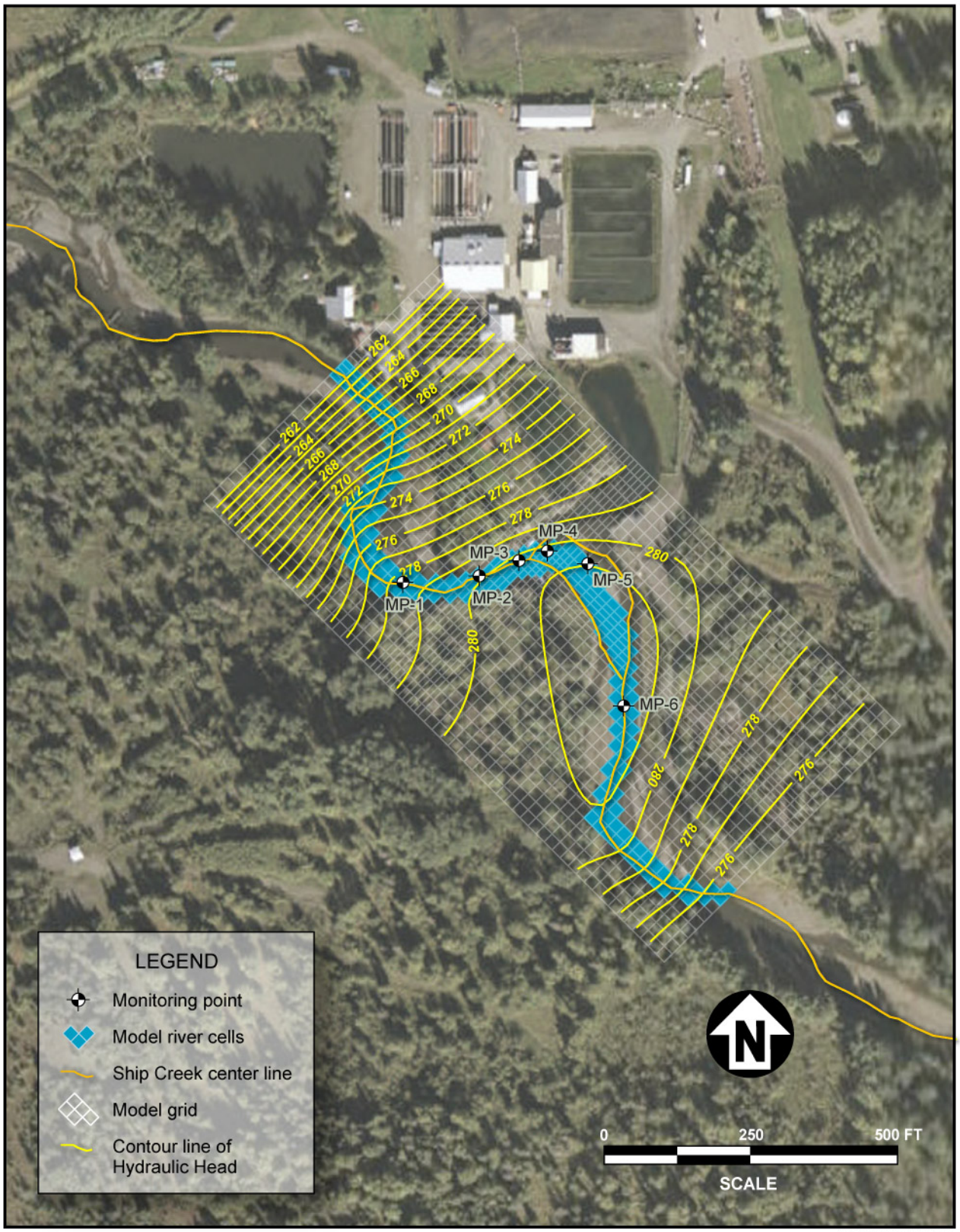

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Figure 7

Model-Predicted Hydraulic Head, K=100 ft/day, No Dam

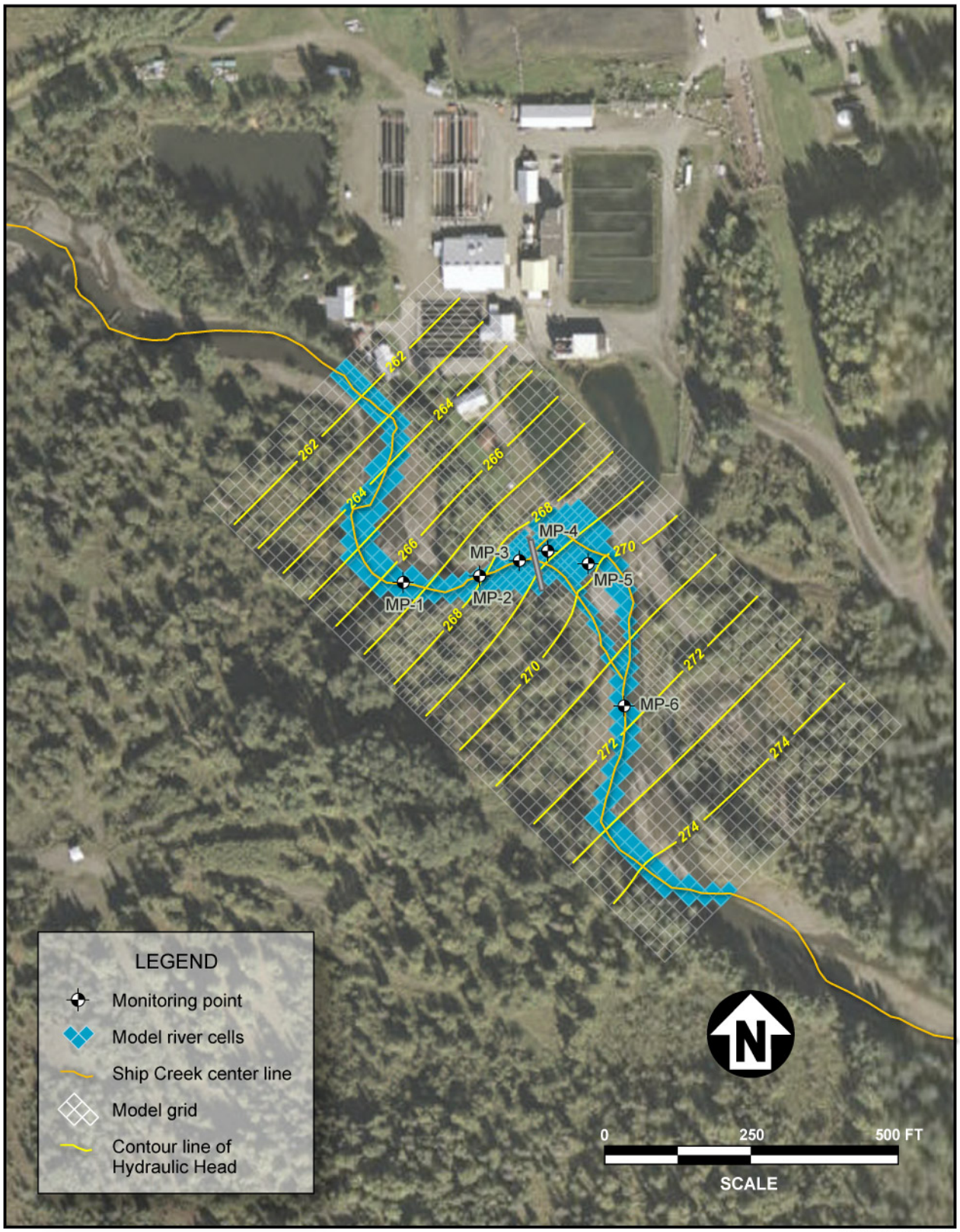

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Figure 8

Model-Predicted Hydraulic Head, K=200 ft/day, Dam Present

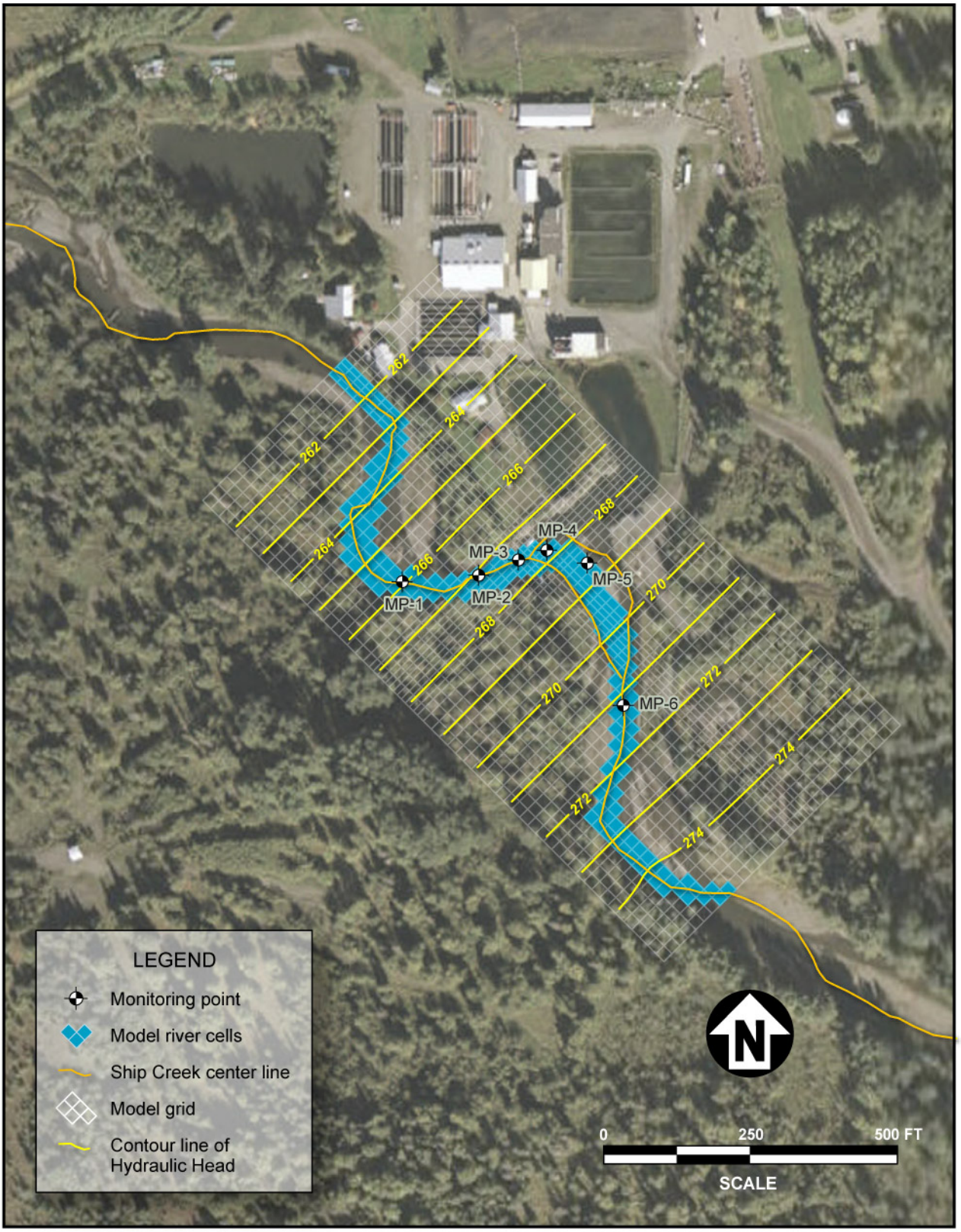

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Figure 9

Model-Predicted Hydraulic Head, K=200 ft/day, No Dam

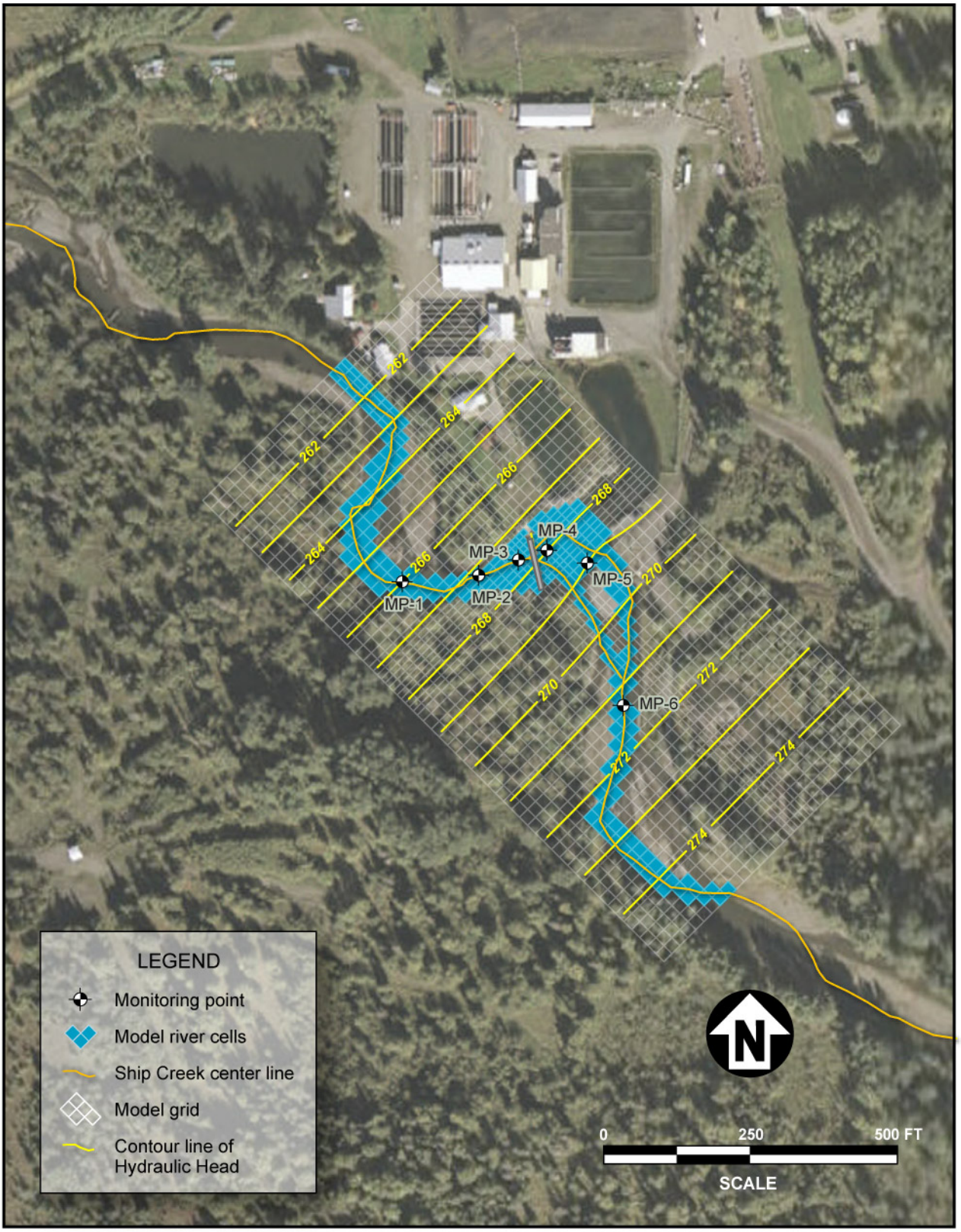

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Figure 10

Model-Predicted Hydraulic Head, K=300 ft/day, Dam Present

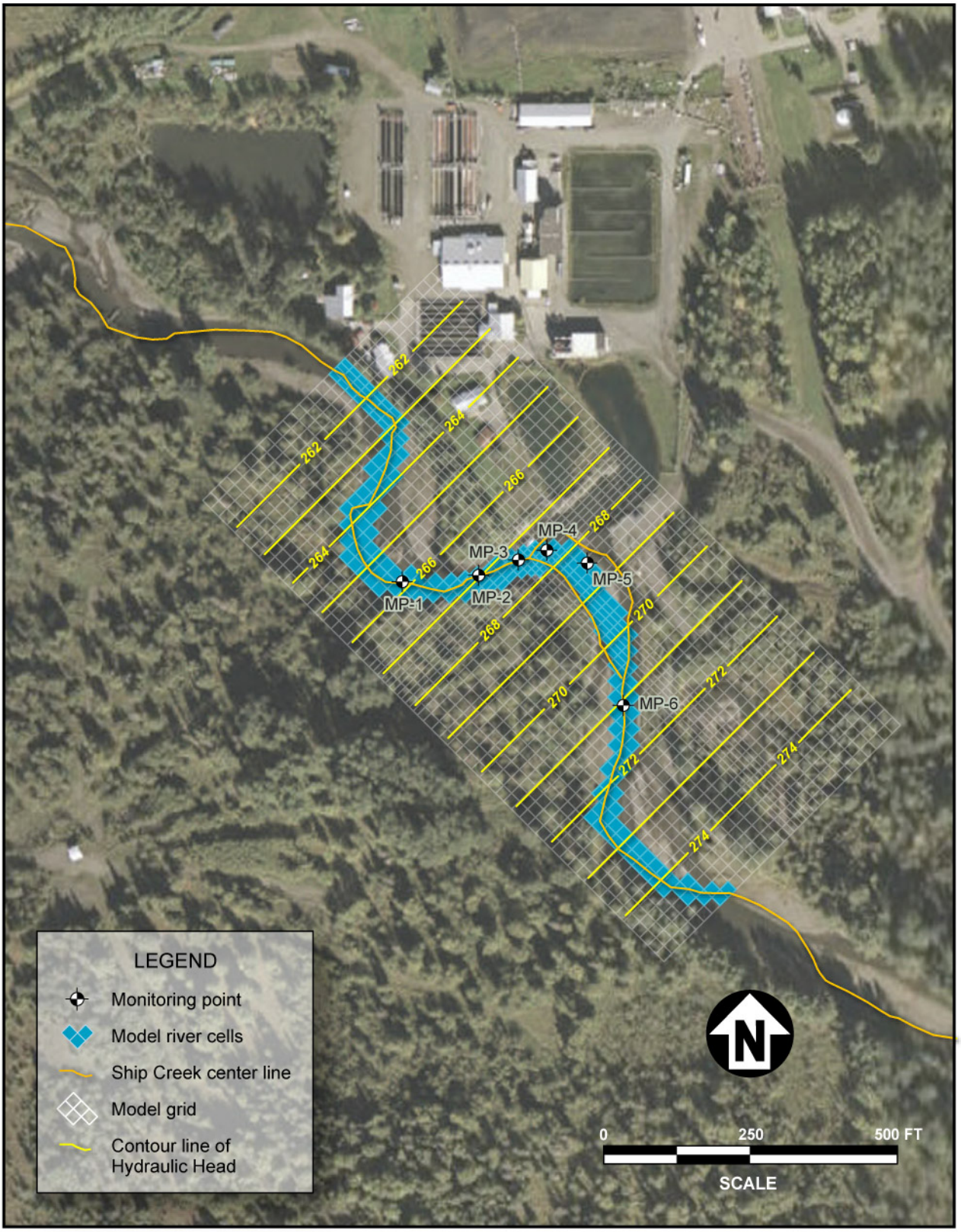

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Figure 11

Model-Predicted Hydraulic Head, K=300 ft/day, No Dam

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Figure 12
Ship Creek Near Elmendorf AFB

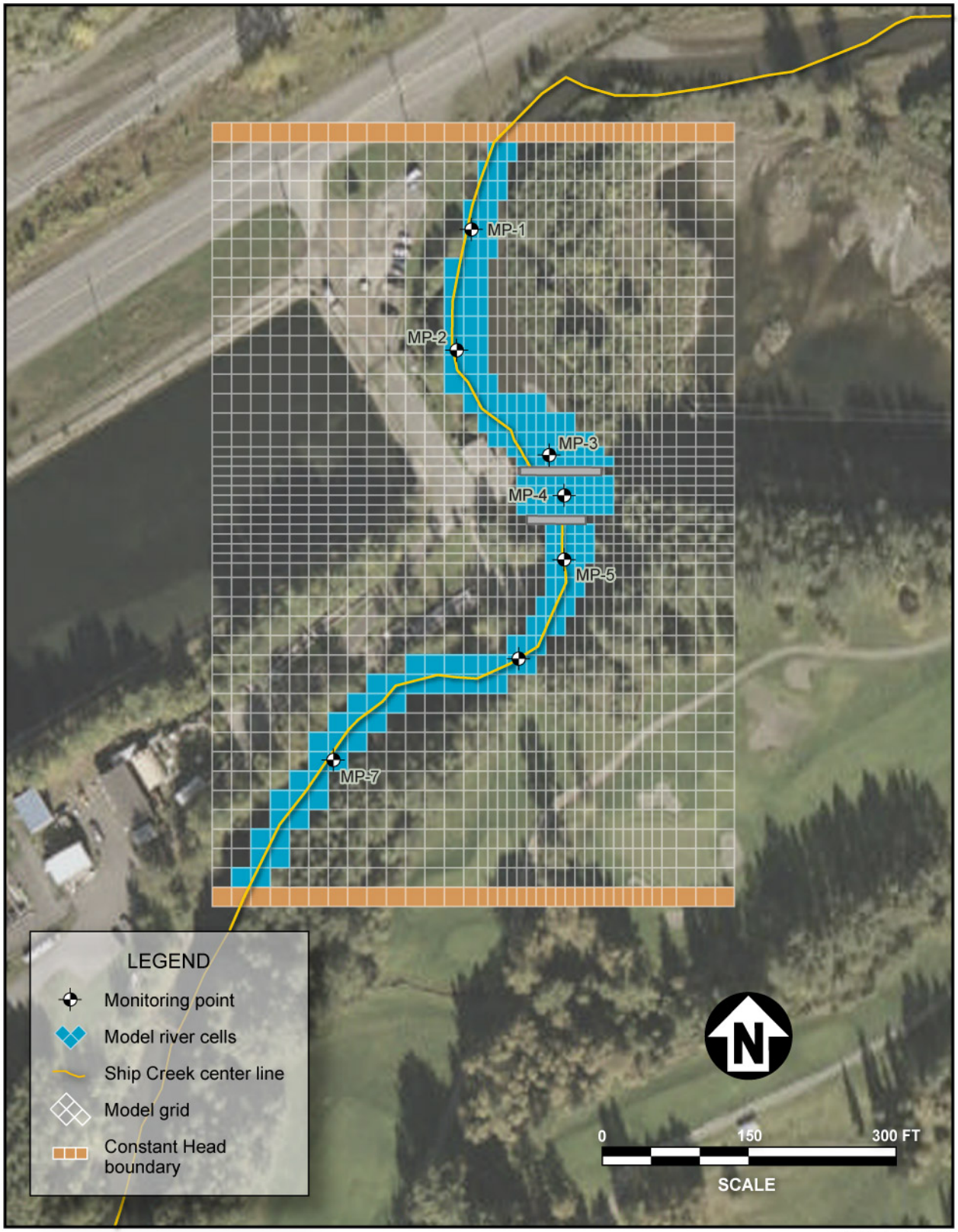

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Figure 13

Elmendorf Model Domain, with Dams Present

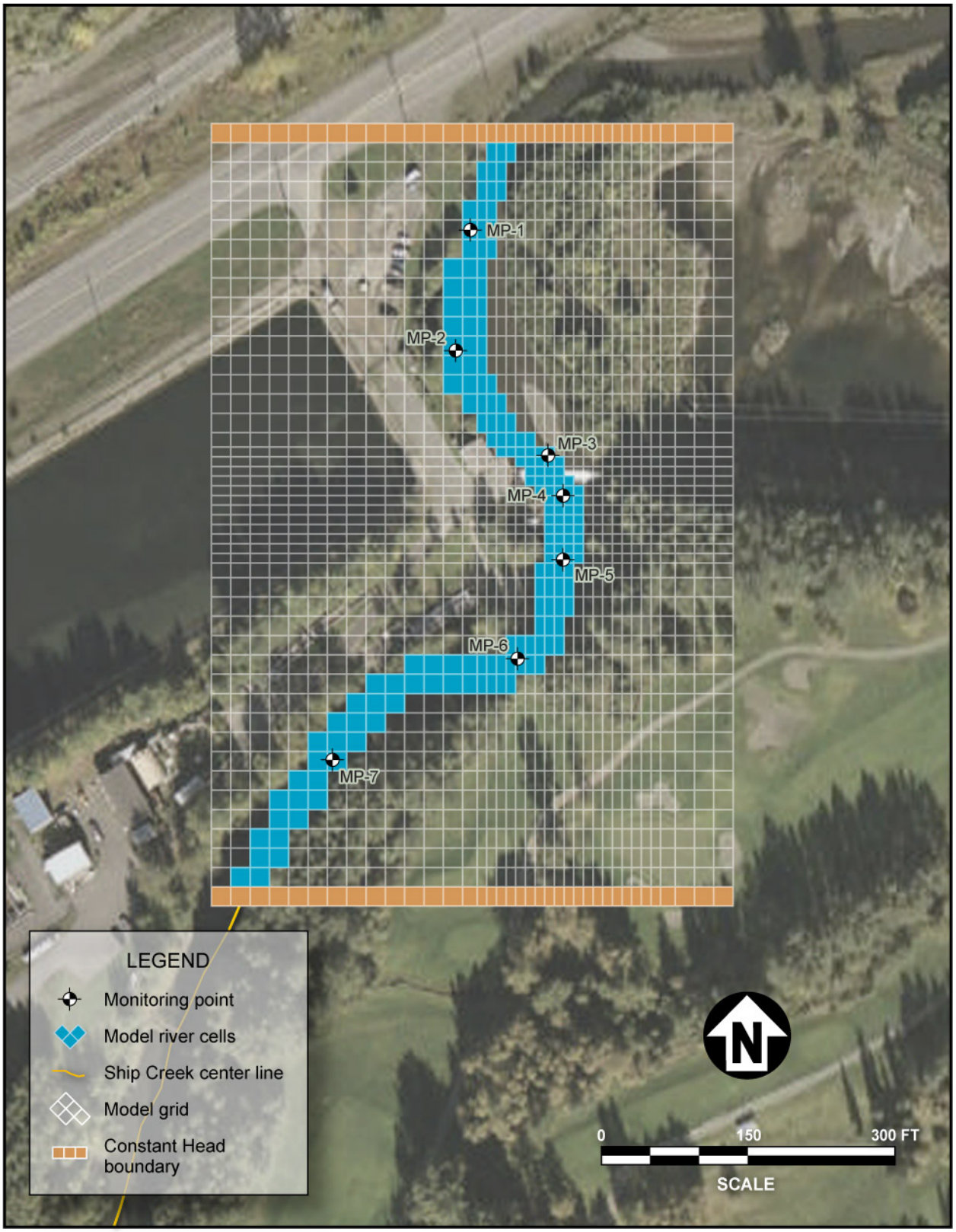

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Figure 14
Elmendorf Model Domain, without Dams

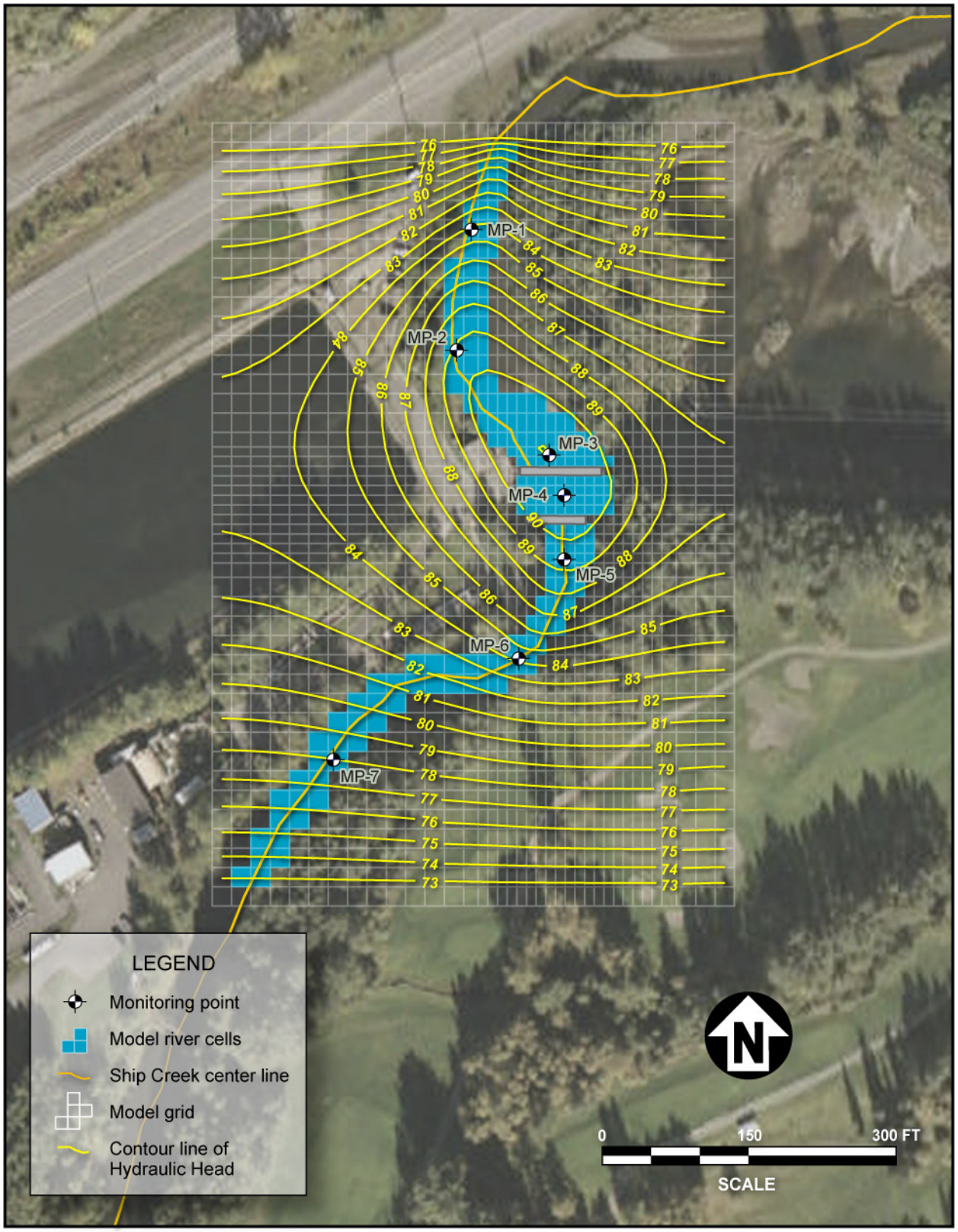

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Figure 15

Model-Predicted Hydraulic Head, K=50 ft/day, Dams Present

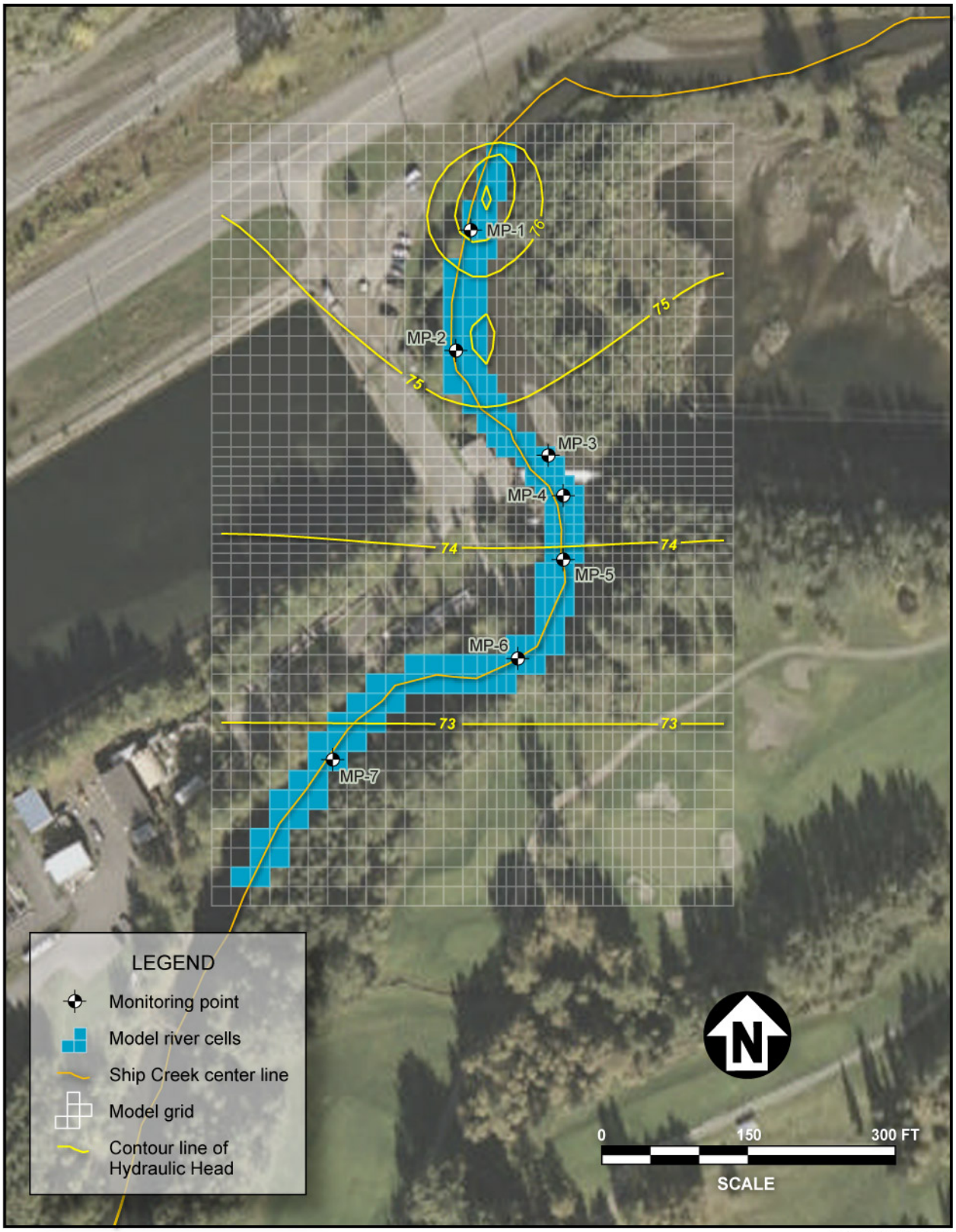

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Figure 16

Model-Predicted Hydraulic Head, K=50 ft/day, No Dams

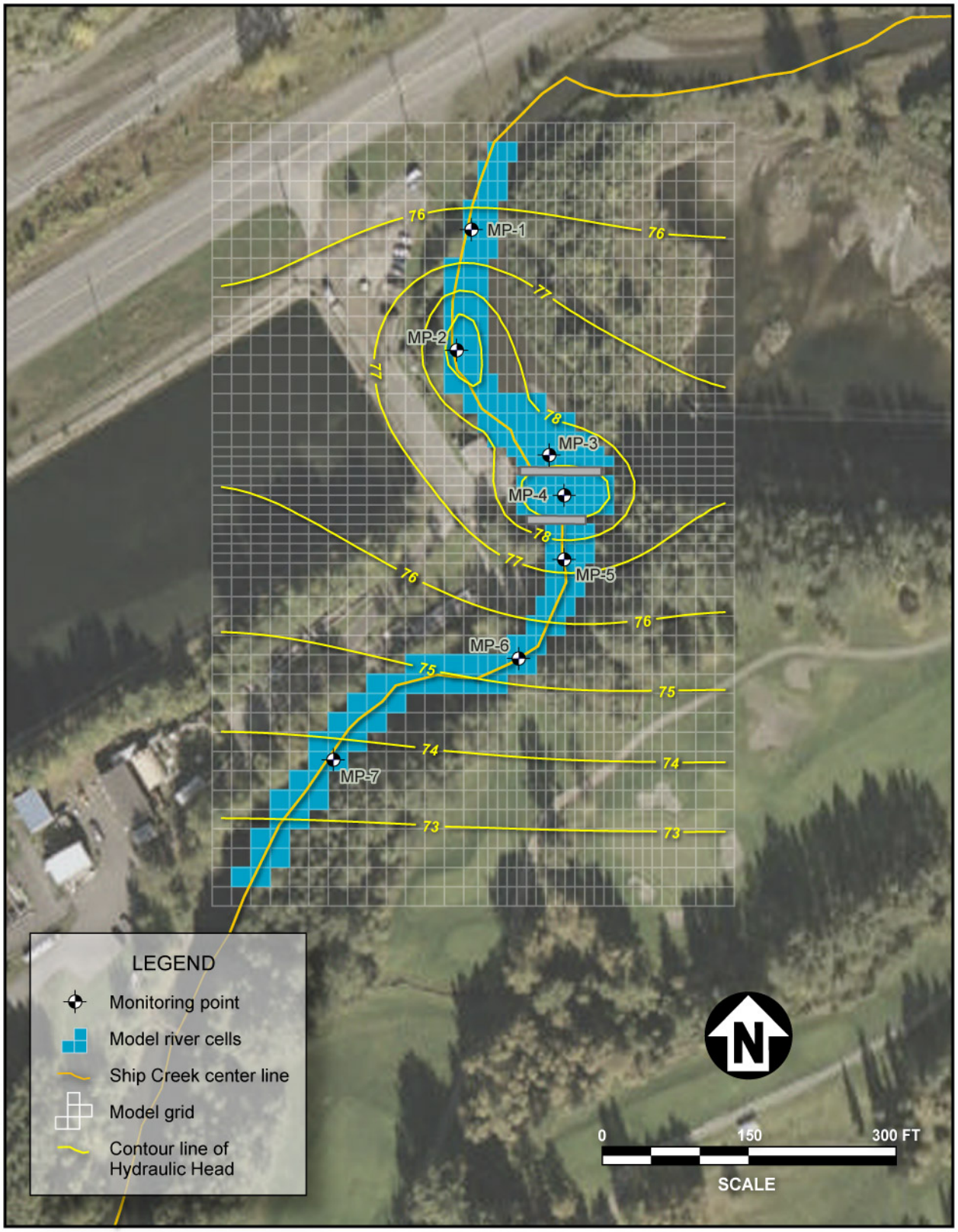

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Figure 17

Model-Predicted Hydraulic Head, K=100 ft/day, Dams Present

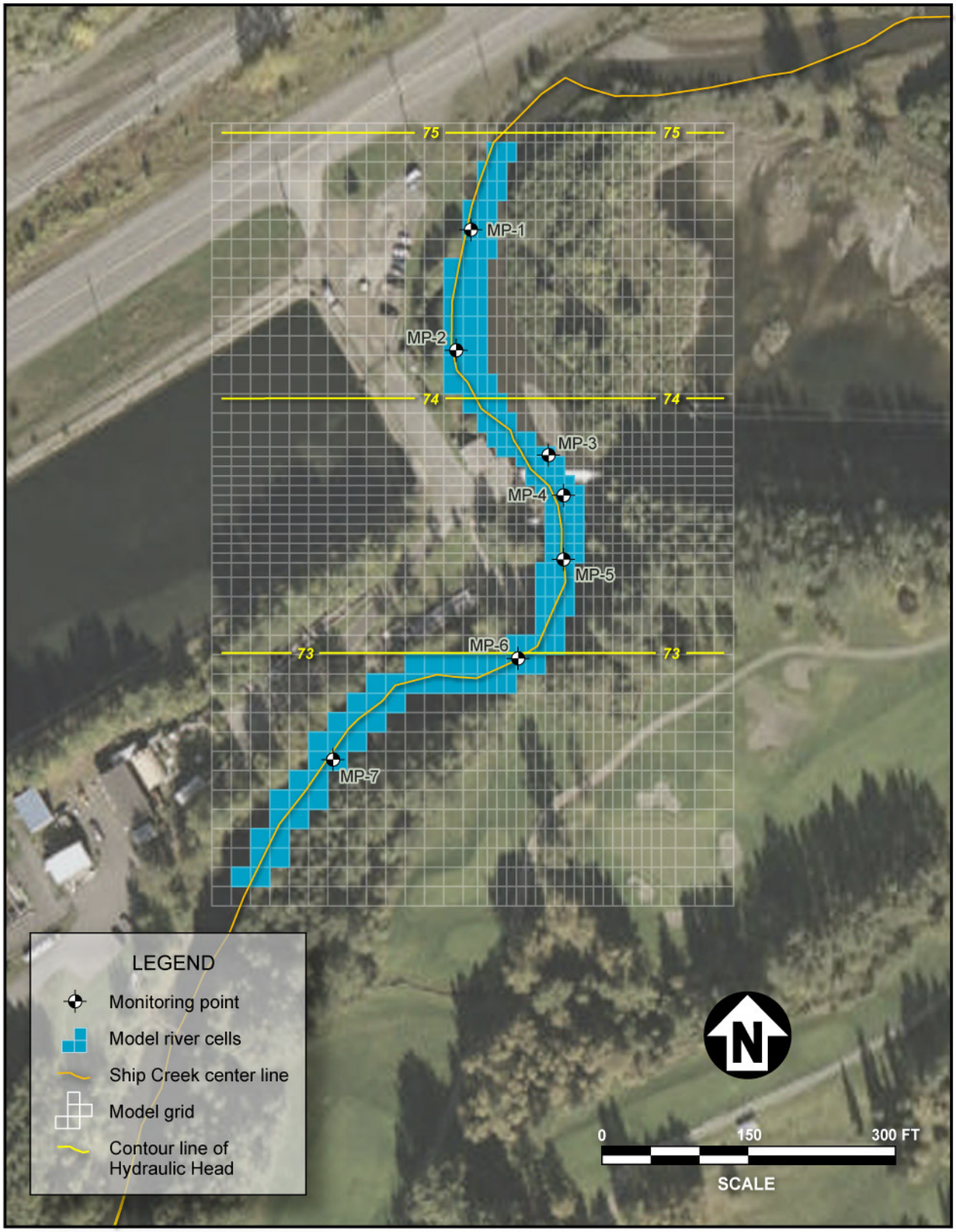

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Figure 18

Model-Predicted Hydraulic Head, K=100 ft/day, No Dams

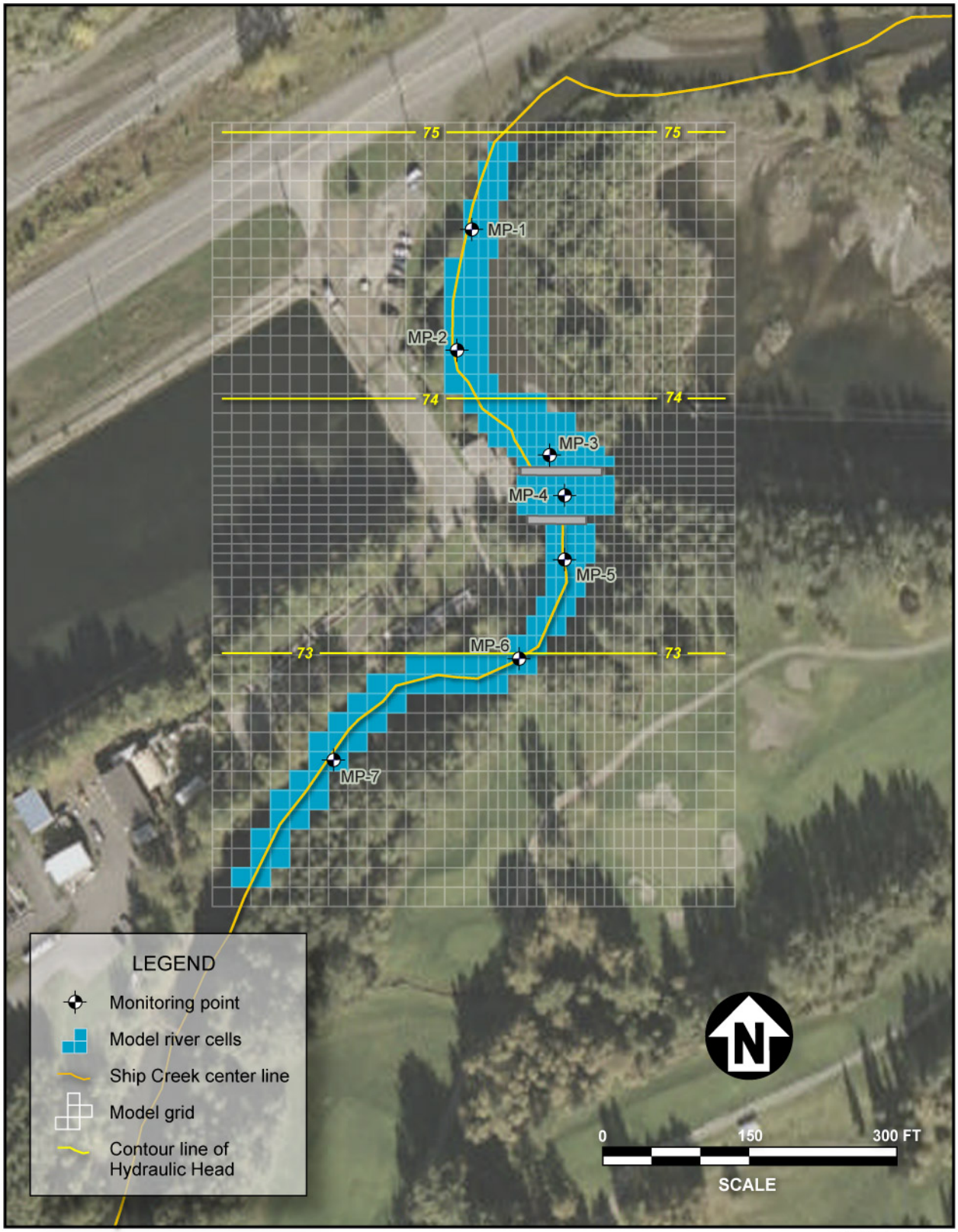

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Figure 19

Model-Predicted Hydraulic Head, K=200 ft/day, Dams Present

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Figure 20

Model-Predicted Hydraulic Head, K=200 ft/day, No Dams

Tables

Table 1
Summary of Hydraulic Parameters

Parameter	Units	Range of Values
Aquifer hydraulic Conductivity	feet per day	50–300
Recharge	inches per year	15; 16
Depth of Ship Creek	feet per day	2–9
Width of Ship Creek	feet	20–100
Thickness of creek bed material	feet	1
Vertical hydraulic conductivity of creek bed	feet per day	0.5–1.0

Table 2
Summary of Water Levels at Monitoring Points (K=50 ft/day)
Ship Creek at Ft. Richardson, AK

Target	Model-Predicted Water Level		Difference
	With Dam	Without Dam	
MP-1	283.89	283.67	-0.22
MP-2	284.57	283.42	-1.15
MP-3	284.11	283.02	-1.09
MP-4	284.00	283.14	-0.86
MP-5	283.66	283.08	-0.58
MP-6	282.45	282.12	-0.33
Average			-0.71

Table 3
Summary of Water Levels at Monitoring Points (K=100 ft/day)
Ship Creek at Ft. Richardson, AK

Target	Model-Predicted Water Level		Difference
	With Dam	Without Dam	
MP-1	282.11	281.56	-0.55
MP-2	282.78	280.96	-1.82
MP-3	282.11	280.28	-1.83
MP-4	281.90	280.26	-1.64
MP-5	281.22	279.86	-1.36
MP-6	279.39	278.41	-0.98
Average			-1.36

Table 4
Summary of Water Levels at Monitoring Points (K=200 ft/day)
Ship Creek at Ft. Richardson, AK

Target	Model-Predicted Water Level		Difference
	With Dam	Without Dam	
MP-1	271.70	271.21	-0.49
MP-2	269.73	268.59	-1.14
MP-3	268.86	267.80	-1.06
MP-4	268.70	267.60	-1.10
MP-5	267.89	267.11	-0.78
MP-6	266.49	265.94	-0.55
Average			-0.85

Table 5
Summary of Water Levels at Monitoring Points (K=300 ft/day)
Ship Creek at Ft. Richardson, AK

Target	Model-Predicted Water Level		Difference
	With Dam	Without Dam	
MP-1	271.29	271.1	-0.19
MP-2	268.99	268.47	-0.52
MP-3	267.99	267.65	-0.34
MP-4	267.64	267.35	-0.29
MP-5	267.21	266.97	-0.24
MP-6	266.02	265.84	-0.18
Average			-0.29

Table 6
Summary of Water Levels at Monitoring Points (K=50 ft/day)
Ship Creek at Elmendorf AFB, AK

Target	Model-Predicted Water Level		Difference
	With Dam	Without Dam	
MP-1	84.28	77.68	-6.6
MP-2	89.20	75.60	-13.6
MP-3	91.00	74.52	-16.5
MP-4	90.91	74.29	-16.6
MP-5	89.41	73.93	-15.5
MP-6	84.22	73.37	-10.9
MP-7	77.98	72.79	-5.2
Average			-12.1

Table 7
Summary of Water Levels at Monitoring Points (K=100 ft/day)
Ship Creek at Elmendorf AFB, AK

Target	Model-Predicted Water Level		Difference
	With Dam	Without Dam	
MP-1	76.33	74.64	-1.7
MP-2	79.44	74.18	-5.3
MP-3	78.63	73.77	-4.9
MP-4	79.85	73.62	-6.2
MP-5	77.33	73.37	-4.0
MP-6	75.37	72.98	-2.4
MP-7	73.74	72.57	-1.2
Average			-3.7

Table 8
Summary of Water Levels at Monitoring Points (K=200 ft/day)
Ship Creek at Elmendorf AFB, AK

Target	Model-Predicted Water Level		Difference
	With Dam	Without Dam	
MP-1	74.64	74.64	0.0
MP-2	74.18	74.18	0.0
MP-3	73.78	73.77	0.0
MP-4	73.62	73.62	0.0
MP-5	73.37	73.37	0.0
MP-6	72.98	72.98	0.0
MP-7	72.57	72.57	0.0
Average			0.0