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Groundwater Model Assessment Report - Proposed City of North Platte Well Field

Prepared for Miller and Associates Consulting Engineers, PC by the Platte River Cooperative Hydrology Study Technical Committee[1]

Overview

By request of Miller and Associates Consulting Engineers, PC, McCook, Nebraska (hereafter referred to as Miller and Associates), the Platte River Cooperative Hydrology Study (COHYST) Technical Committee utilized the COHYST groundwater flow model of the COHYST Central Model Unit to provide an assessment of impacts to Whitehorse Creek and the High Plains aquifer in the area of the proposed city of North Platte, Nebraska well field. This report contains results from a series of model simulations designed to provide an assessment of future well field impacts on Whitehorse Creek and the regional aquifer.

Methodology

As requested by Miller and Associates, the COHYST development period groundwater flow model was used to determine future impacts of the proposed city of North Platte well field (fig. 1). To provide a comparative assessment of future impacts of the proposed well field, four scenarios were simulated with the COHYST model. These scenarios include

1) Ambient conditions with no additional stresses on the system

2) 26 irrigation wells (4 per section) in the proposed well field location pumping 12 inches per pumping season on 130 acres (per well) for 48 years

3) The proposed well locations pumping with seasonal averages of future predicted pumping rates provided by Miller and Associates

4) The proposed well locations pumping with an annual average rate to meet the future predicted needs for the city of North Platte

[1] The Platte River Cooperative Hydrology Study Technical Committee is comprised of engineers, scientists, and managers from several cooperating agencies in Nebraska that formed and investigative team in the late 1990's to produce models, databases, and other analyses in the Platte River basin from Columbus to Scottsbluff. Contact information for committee members regarding this investigation are:

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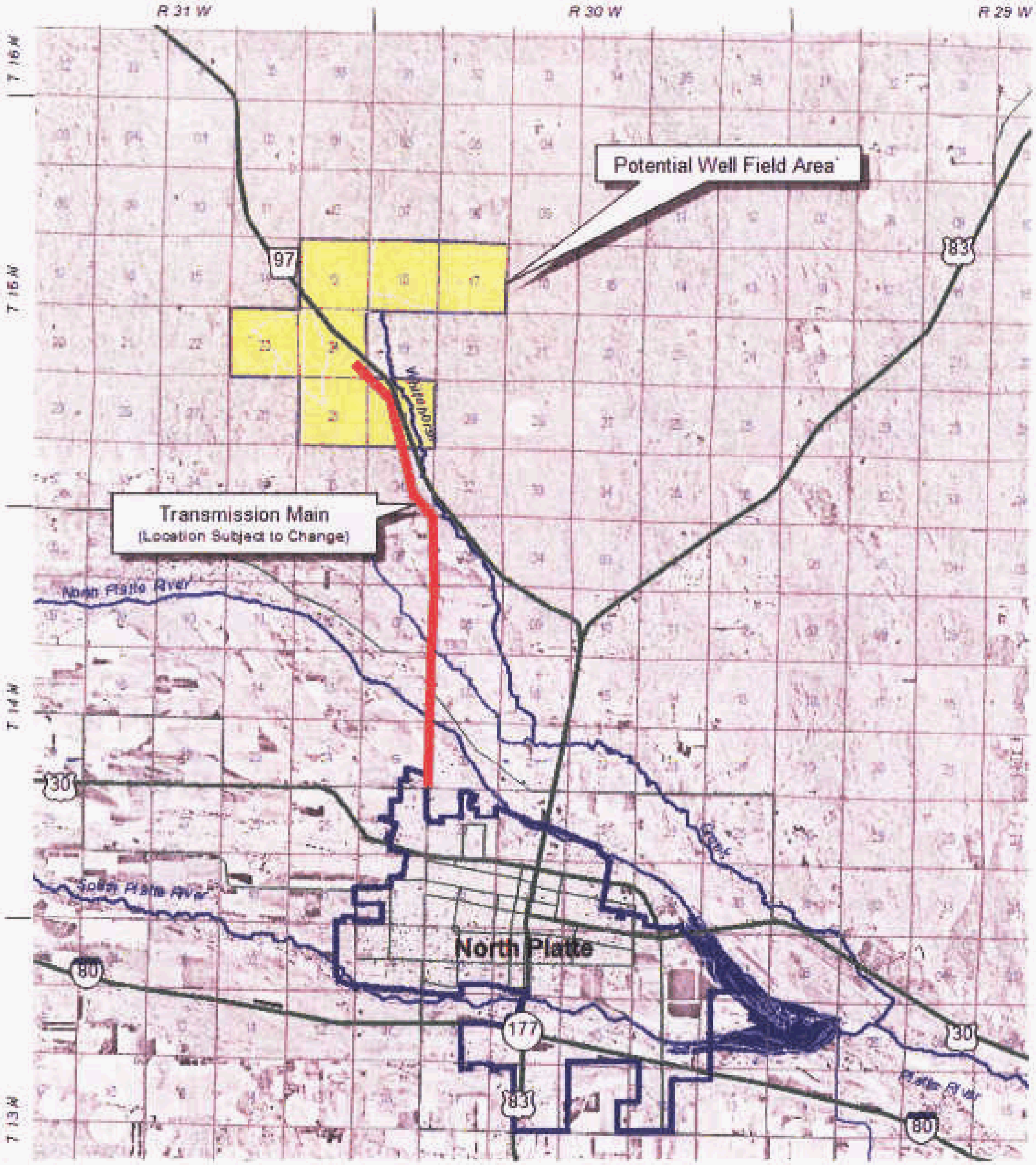

Prepared By:

Miller Associates
CONSULTING ENGINEERS, P.C.

Figure 1
Project Location
North Platte, Nebraska

Model Area

The area of interest is located approximately 7 miles north of the city of North Platte in central Lincoln County, Nebraska (fig. 1). Seven sections were selected by Miller and Associates for potential well locations within Township 15 North and Ranges 30 and 31 West. State Hwy 97 roughly bisects the well field area. The headwater area of Whitehorse Creek is located in section 9 of Township 15 north Range 30 west. Whitehorse Creek baseflow (stream flow comprised of groundwater contribution to flow only) has been estimated to range between 6 and 9 cubic feet per second (cfs) (COHYST, 2001). Periodic stream flows often exceed this range. However, this additional flow is comprised of surface runoff from precipitation events or irrigation runoff. The topography of the well field area is comprised of gently rolling to hummocky dunes on the southern edge of the Nebraska Sand Hills. The saturated thickness of the High Plains aquifer in this area ranges from 325 to over 425 feet. The High Plains aquifer increases in thickness in a northward trend across the area of interest in this report. The regional groundwater flow trends in a north/northwest to south/southeast direction. The aquifer in this area is comprised of Quaternary and Pliocene age sand and gravel unit which can approach 100 feet in thickness in the area of the proposed well field. Underlying the Quaternary/Pliocene sediments is the Ogallala Group, which can exceed 300 feet in thickness in the area of interest. The Ogallala Group consists of interbedded and unconsolidated silts, sands, gravels and semi-consolidated sandstones, siltstones, claystones. The top of the Oligocene Brule Formation (White River Group) is considered the bottom of the High Plains aquifer in this area of Lincoln County.

Model Characteristics and Data Inputs

The groundwater model used for the analysis presented in this report was designed, constructed, and calibrated by the COHYST Technical Committee (http://cohyst.nrc.state.ne.us/). The model was constructed using the MODFLOW-96 code. Data was added to and results retrieved from the model using the Groundwater Modeling System (GMS v. 3.1) pre/post-processor. The simulation used for this assessment represents a 48-year period that was considered the "groundwater development period" from 1950-98. The model accounts for area groundwater pumpage using data prepared for the COHYST simulation. The pumpage values assigned to wells were based on crop consumptive use estimated by Klocke and others (1990, table 1). Crop consumptive use minus effective precipitation is the estimated net irrigation requirement for the crop. Although the simulation described in this report is applied to a period beyond the "development period" as defined by COHYST, the land-use in the area of interest for the proposed well field has historically consisted of rangeland and has not been extensively developed in the last 50 years. Considering this condition in the area of interest, the COHYST model was deemed suitable for this analysis.

The model consists of 6 layers representing various hydrostratigraphic units within the High Plains aquifer. Layers 1-3 represent Quaternary- to Tertiary-age units that are typically unconsolidated. Layers 3, 4 and 5 represent the Ogallala Group, and Layer 6 represents the Arikaree Group, which is absent in this area. Model cells are uniform in size, covering an area of 160 acres (quarter square-mile). Cells in which the water table is initially below the bottom of the cell are set as inactive in the simulation, but allowed to become active (or "re-wet") if the water table rises above the bottom of the cell. The external model boundaries north of the area are comprised of a river and constant flow conditions. To the east, a constant flow boundary exists. These boundaries are over 30 miles from the area of interest and should not exert any influences on the simulations described in this report.

Aquifer characteristics such as horizontal and vertical hydraulic conductivity, specific yield, and specific storage were obtained after calibration of the COHYST model and were originally obtained from the COHYST geologic borehole database that comprises of geologic borehole logs from UNL-CSD/USGS testholes as well as irrigation, industrial, municipal, and domestic well logs in the study area.

Recharge to the model is derived from land-use and topographic characteristics. In this area, recharge can exceed 2.5 inches per year in Sand Hills.

Whitehorse Creek is simulated using the Stream Package within MODFLOW-96. Streambed elevations were obtained from the Nebraska Department of Natural Resources. The COHYST model initially simulates an aquifer discharge to the stream at 6 cfs. The North Platte River, into which Whitehorse Creek discharges, is simulated using the River Package.

Wells were simulated using the Well Package in MODFLOW-96. Well locations and pumping rates were first prepared using GIS coverages and entered into MODFLOW-96 within GMS. Although multiple wells may exist in a model cell, MODFLOW simulates one well per cell at the centroid of the cell with an accumulated rate of all wells within the cell. Note the gold squares in the cells containing wells in the simulation result figures indicate this format. Pumpage data and new well locations were provided by Miller and Associates.

Simulated Well Field Scenarios

Miller and Associates provided the COHYST Technical Committee with locations of 10 proposed production wells for the city of North Platte. For the first simulation of ambient conditions with no additional wells in the system, no wells exist in the system with exception of wells implemented in the COHYST model to satisfy the net irrigation requirement. The second test simulation simulated 26 hypothetical irrigation wells (as previously described) in quarter section locations of each section in the proposed well field area. Each well pumped at a rate of 12 inches per pumping season for an area of 130 acres. This simulation ran for 48 years. The hypothetical well locations are shown in figure 2.

Figure 3 shows the approximate well locations for the proposed well field provided by Miller and Associates. The 10 wells were simulated in two separate simulations. The first simulation applied temporally variable pumping rates. The COHYST model is structured to simulate pumping in a stress period representing the growing months of May-September. The remaining seven months is simulated in a stress period representing the non-growing season. From the data provided by Miller and Associates (see appendix), an average pumping rate (for months of May-September) was applied to the growing season stress period. A second averaged rate (October-April) was applied to the non-growing season for each of the 48 years simulated. The average growing-season pumping rate was 10,369 gallons per minute (gpm) distributed evenly to the 10 simulated wells. The average non-growing season pumping rate was 5,152 gpm distributed evenly to the 10 simulated wells. Values in MODFLOW-96 were converted to cubic feet per day. These pumping rates were applied to the initial stress period for the simulation. Current water pumpage for North Platte municipal use is approximately 60% of these pumping rates, therefore the simulation is considered to determine worst case scenario changes to the current groundwater/surface water system.

A second simulation using the proposed well locations in figure 3 applies an average annual rate of 7,449 gallons per minute, distributed evenly to each well and run constant for 48 years.

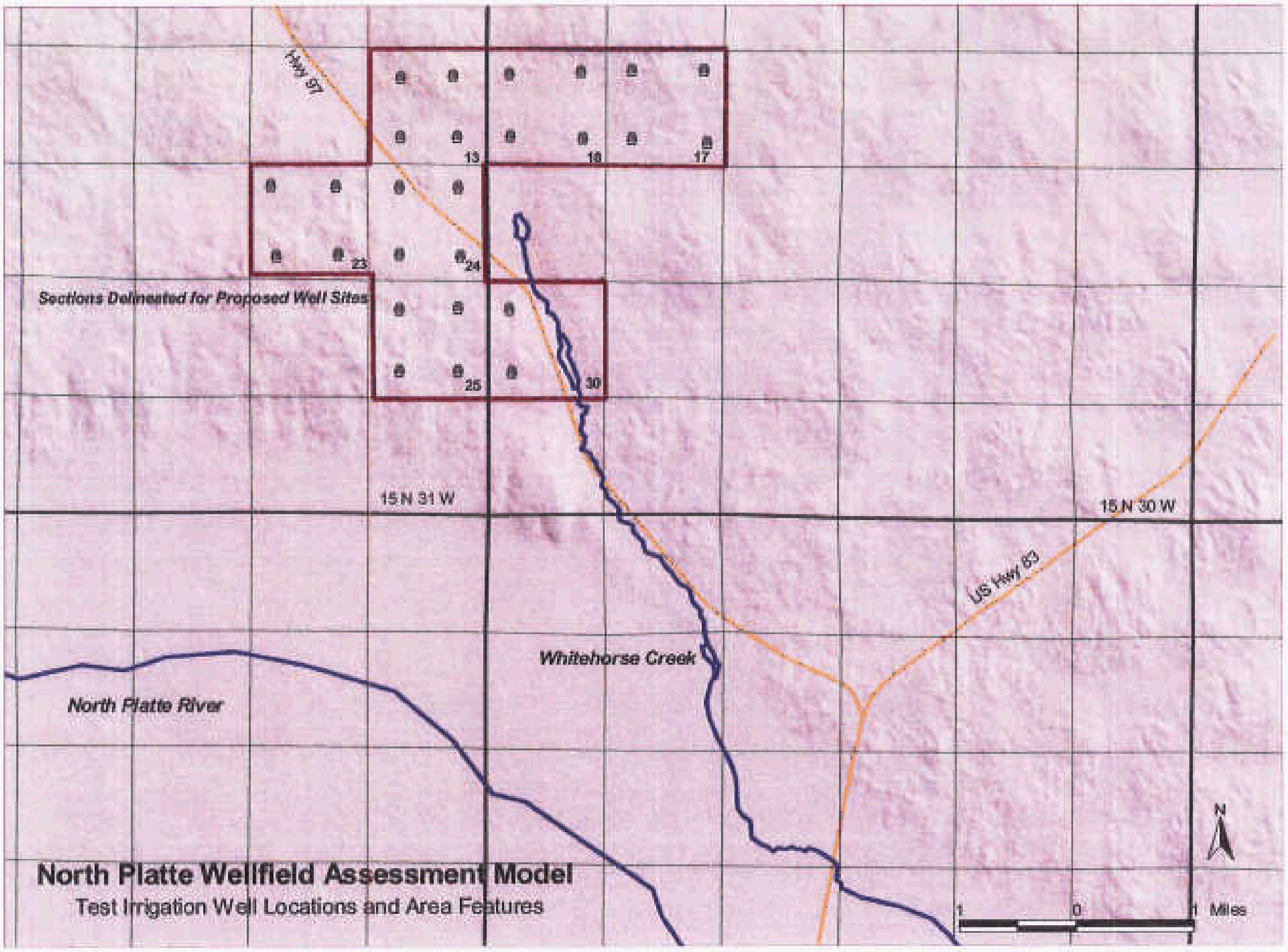

Figure 2. – locations of 26 hypothetical irrigation wells for test simulation.

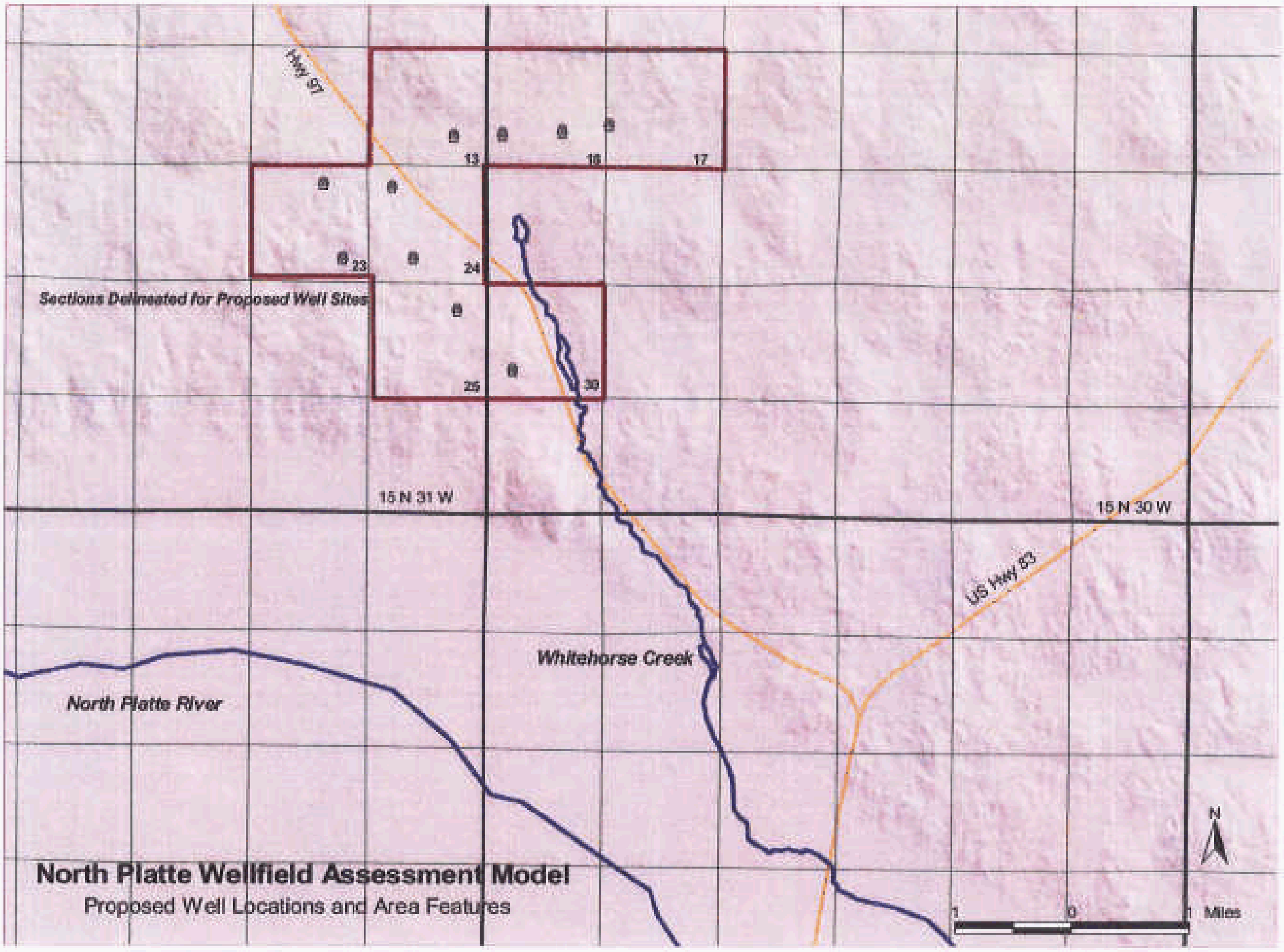

Figure 3. – locations of 10 proposed municipal production wells (wellhead symbols) for the city of North Platte.

Ambient Condition Simulation

The ambient condition simulation was produced to characterize baseline conditions of aquifer discharge to Whitehorse Creek. No additional pumping stresses we applied to the system for the 48 year simulation. Figures 4 shows water table elevation contours at the end of the simulation. Simulated discharge to Whitehorse Creek is summarized in the Long Term Impacts section.

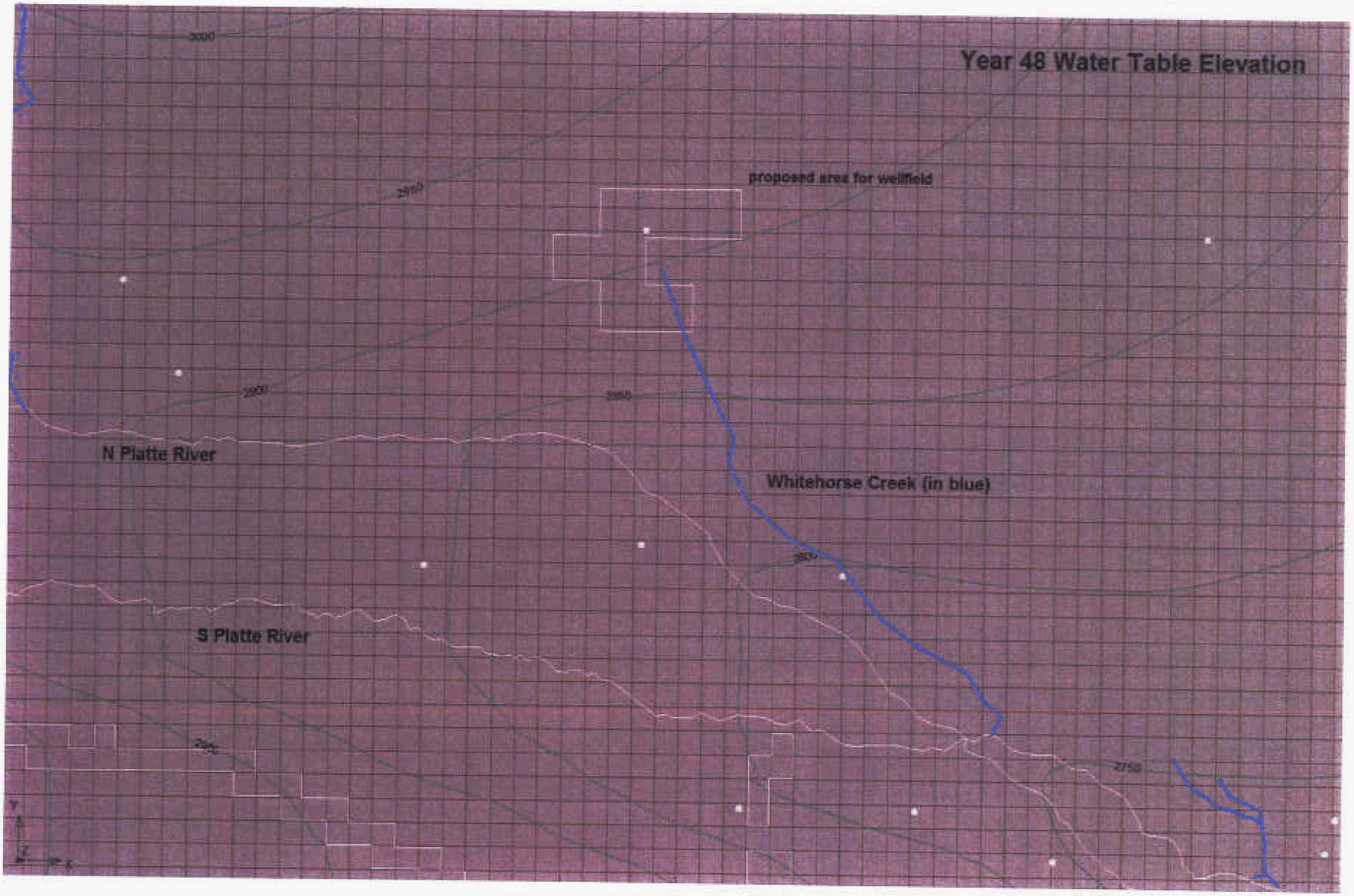

Figure 4. – Simulated water table elevations at the end of the 48-year ambient conditions scenario.

Test Irrigation Wells Simulation Results

For the simulation testing 26 hypothetical irrigation wells in the area of interest, the following figures show the elevation of the water table after 5, 10, 25, and 48 years. The actual well locations are marked with an x, whereas the simulated well location (centroid of the grid cell) is shown gold. Note that in the figures showing water level declines by color fill, the declines occurring to the southwest and northeast of the proposed well field area in the later stages of the pumping scenario are artifacts of the COHYST pumpage data sets where development occurred in the 1980s and 1990s. These areas of drawdown would occur with or without the test irrigation wells simulated in the area of interest for the proposed well field.

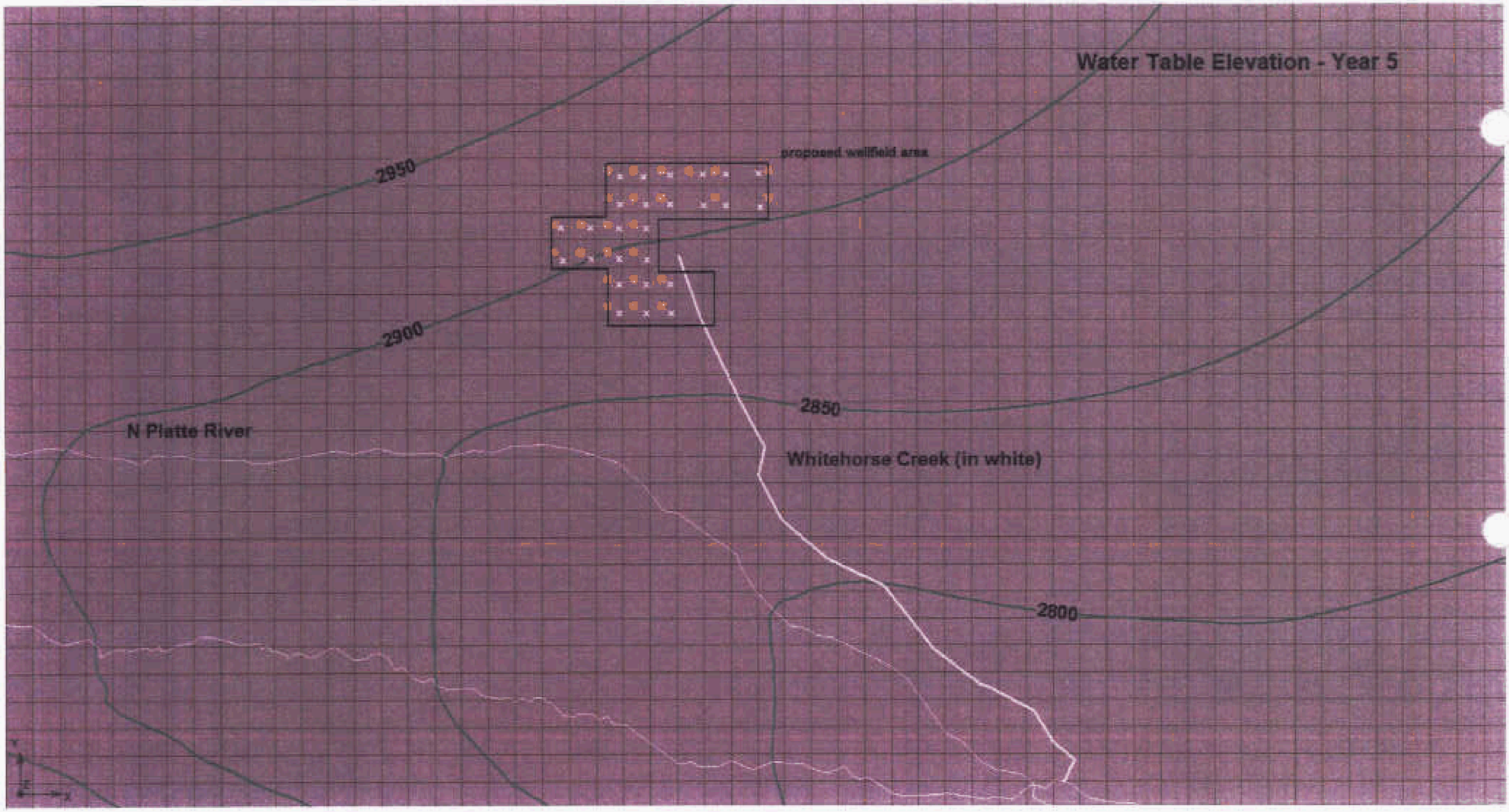

Figure 5. – Water table elevation with the test irrigation well scenario at year 5.

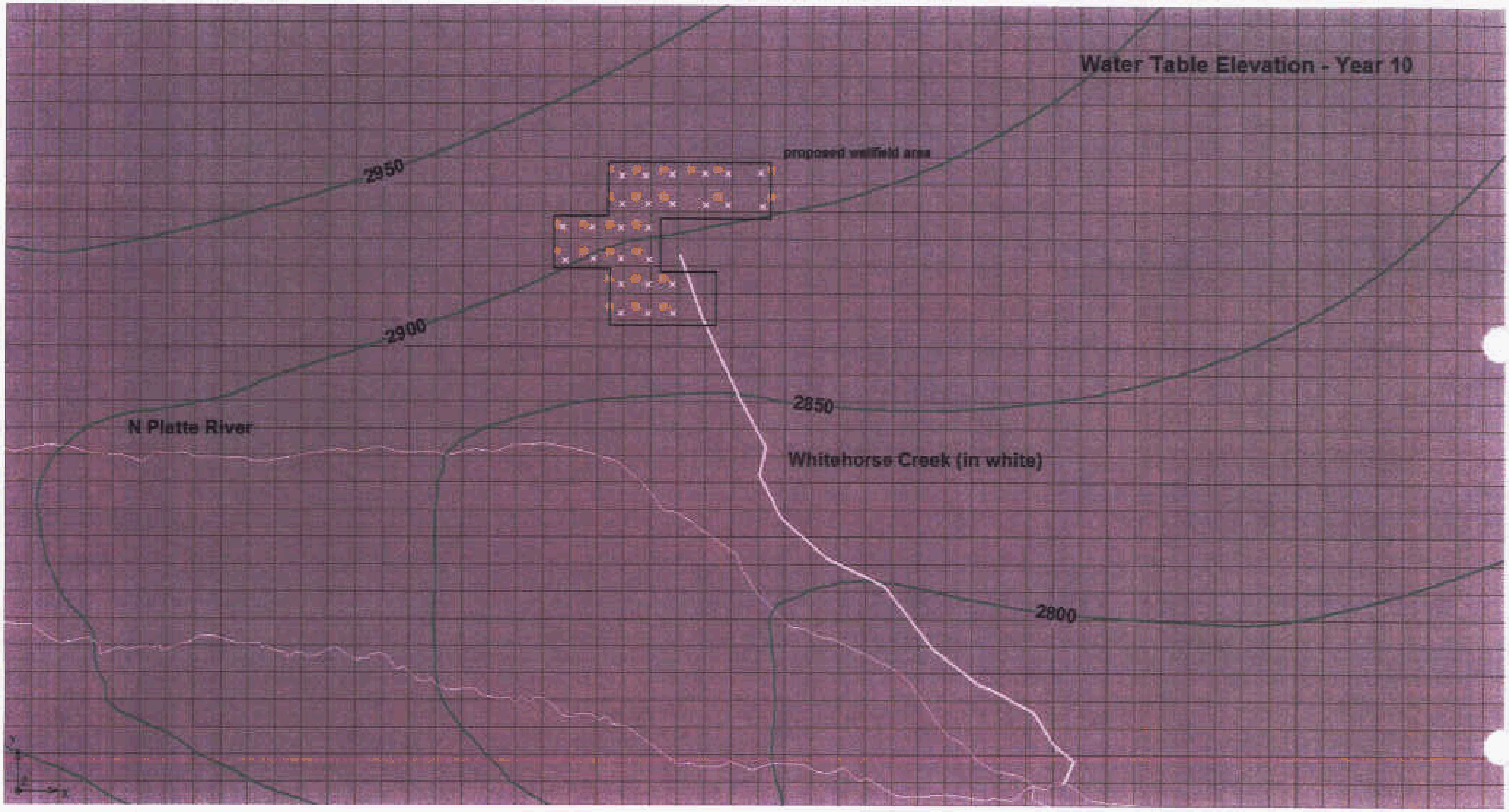

Figure 6. – Water table elevation with the test irrigation well scenario at year 10.

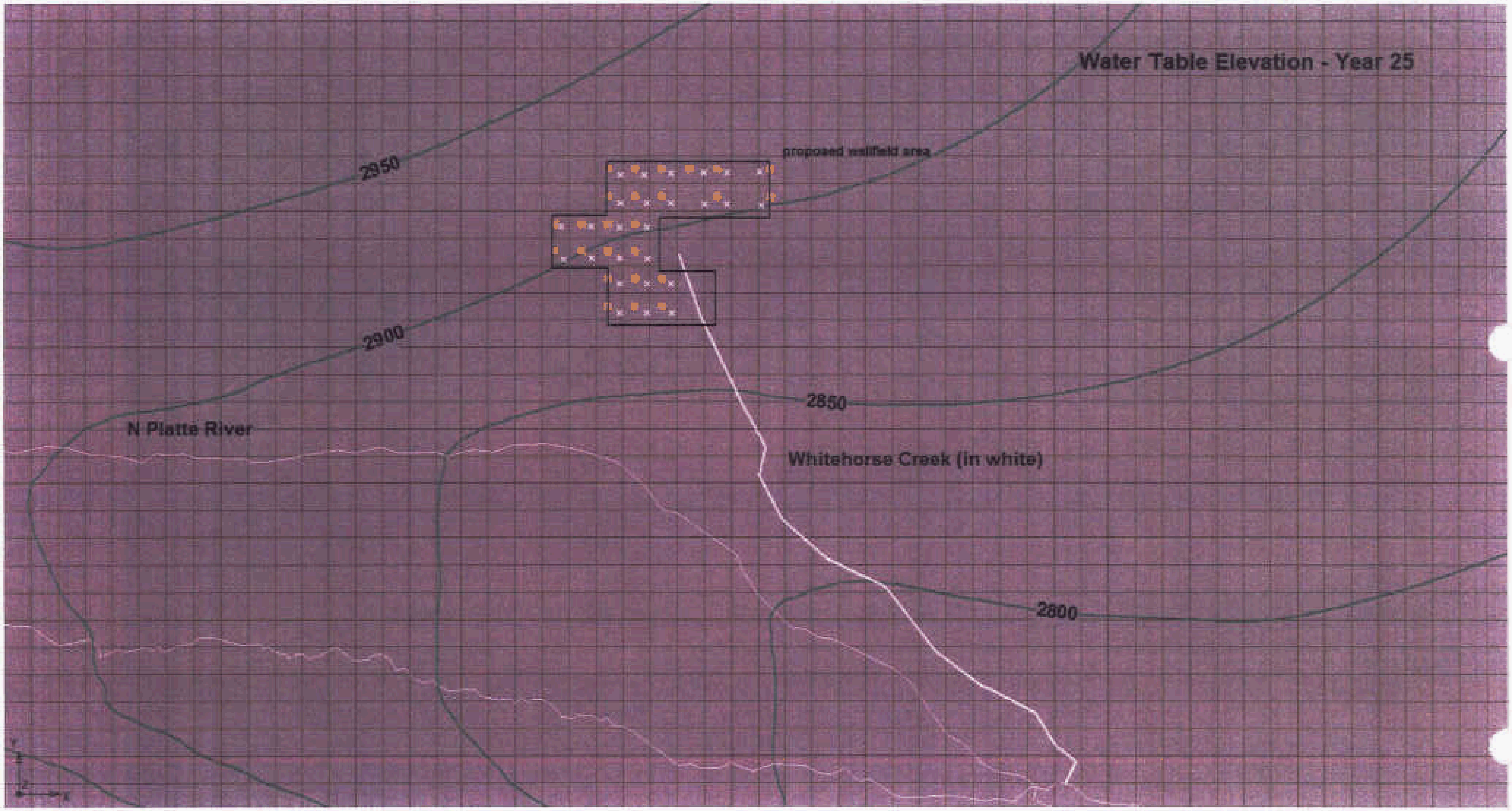

Figure 7. – Water table elevation with the test irrigation well scenario at year 25.

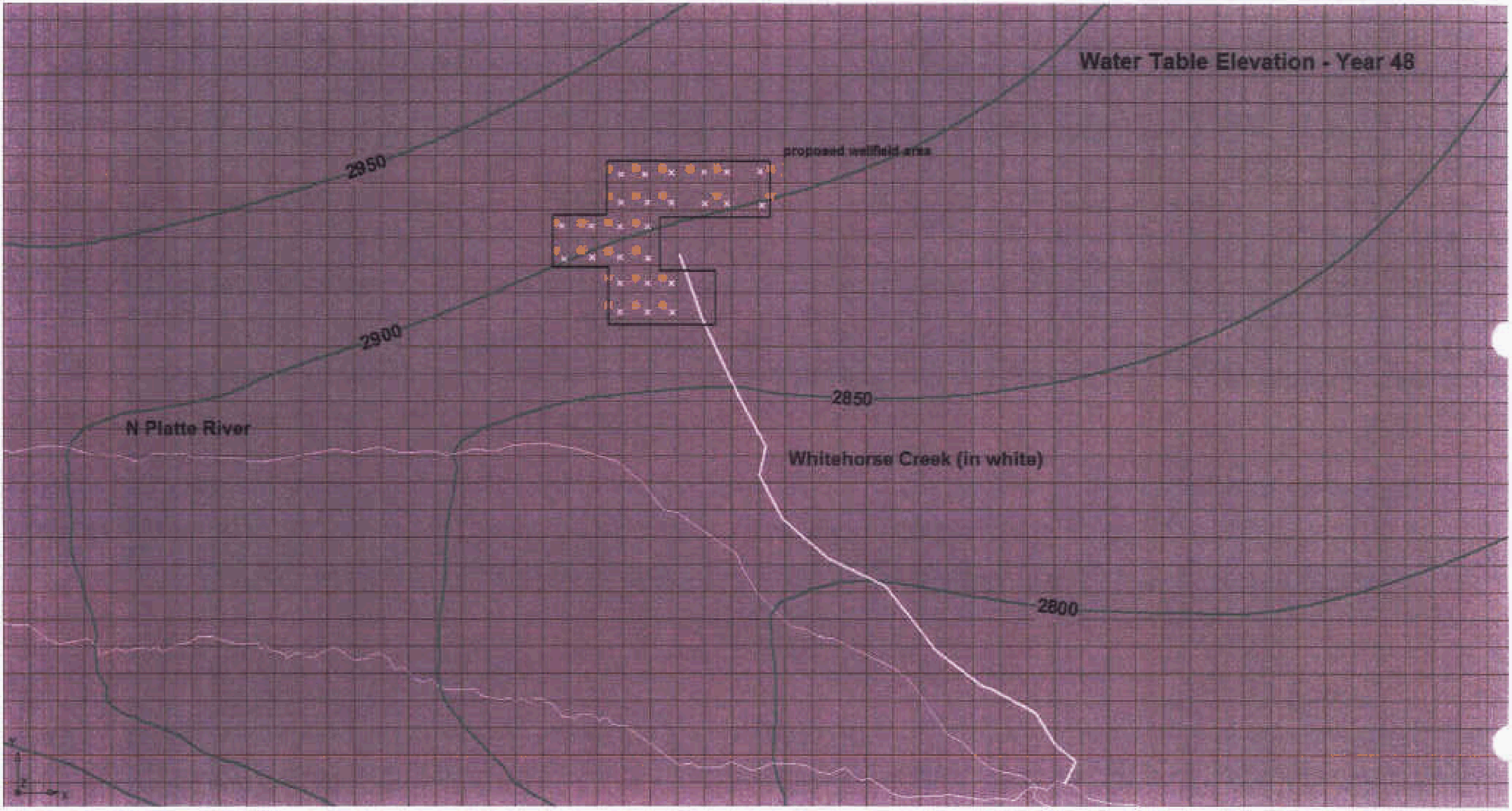

Figure 8. – Water table elevation with the test irrigation well scenario at year 48.

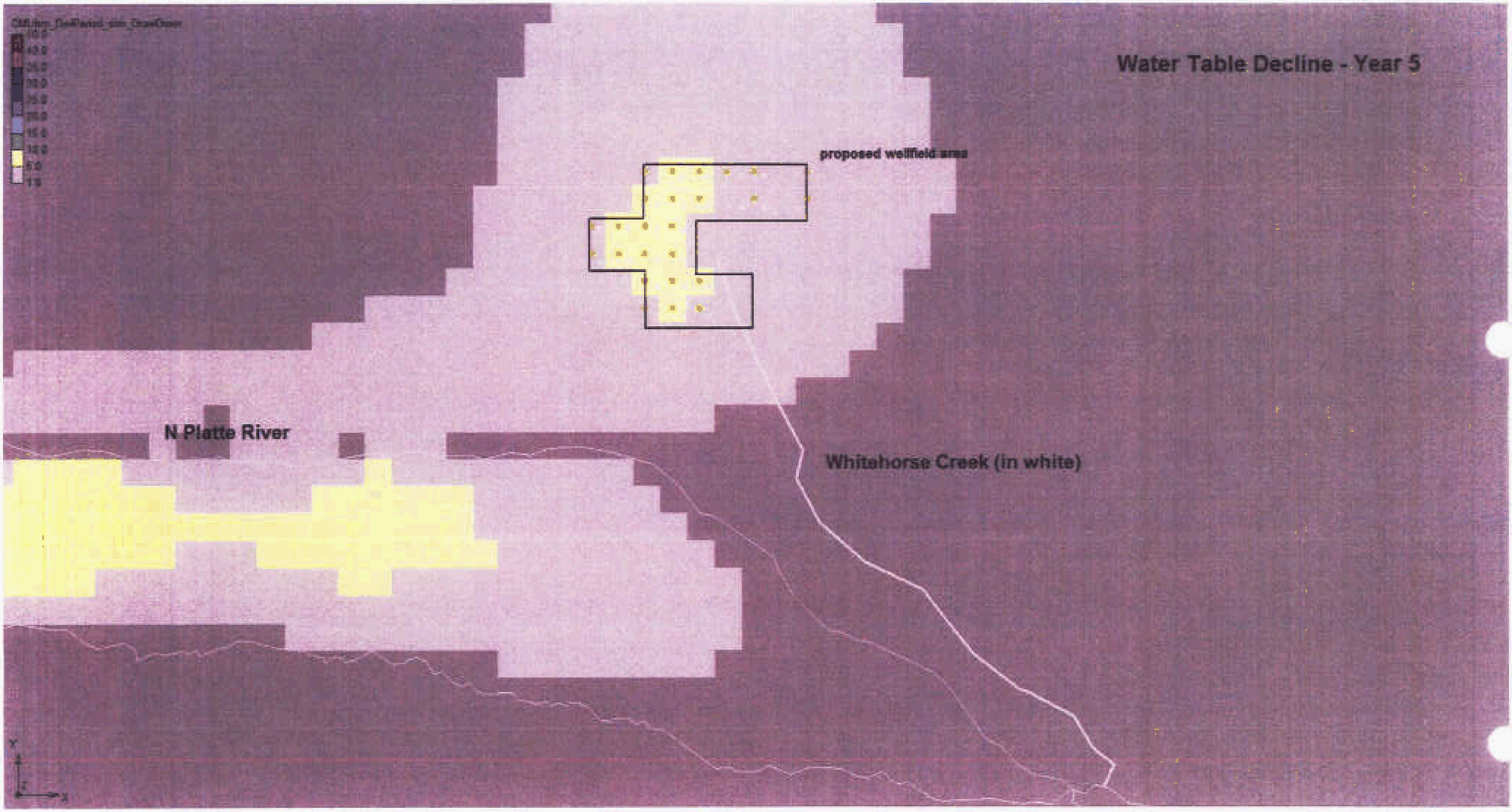

Figure 9. – Water table decline with the test irrigation well scenario at year 5. Color scaling in upper left corner of image.

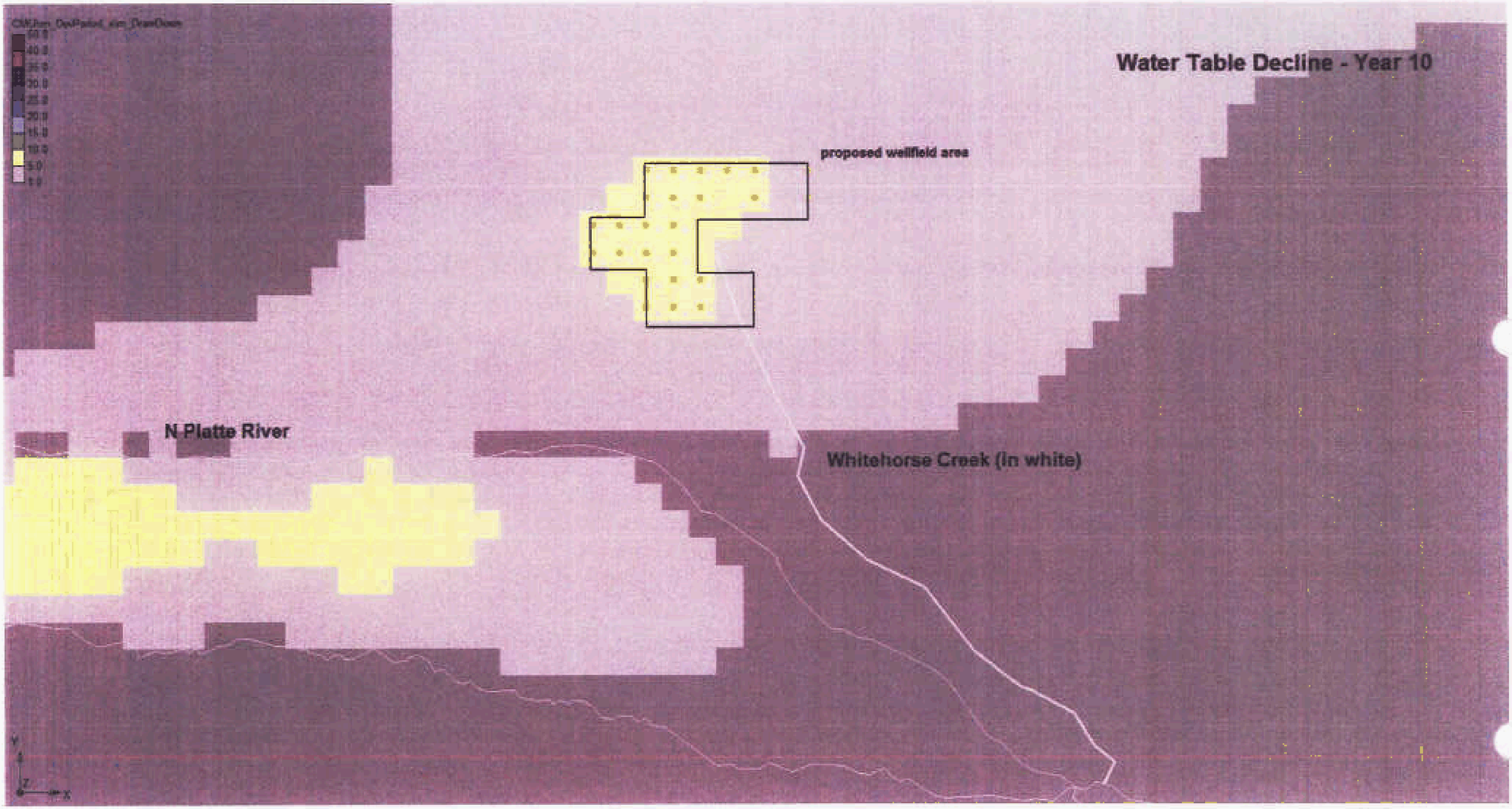

Figure 10. – Water table decline with the test irrigation well scenario at year 10. Color scaling in upper left corner of image.

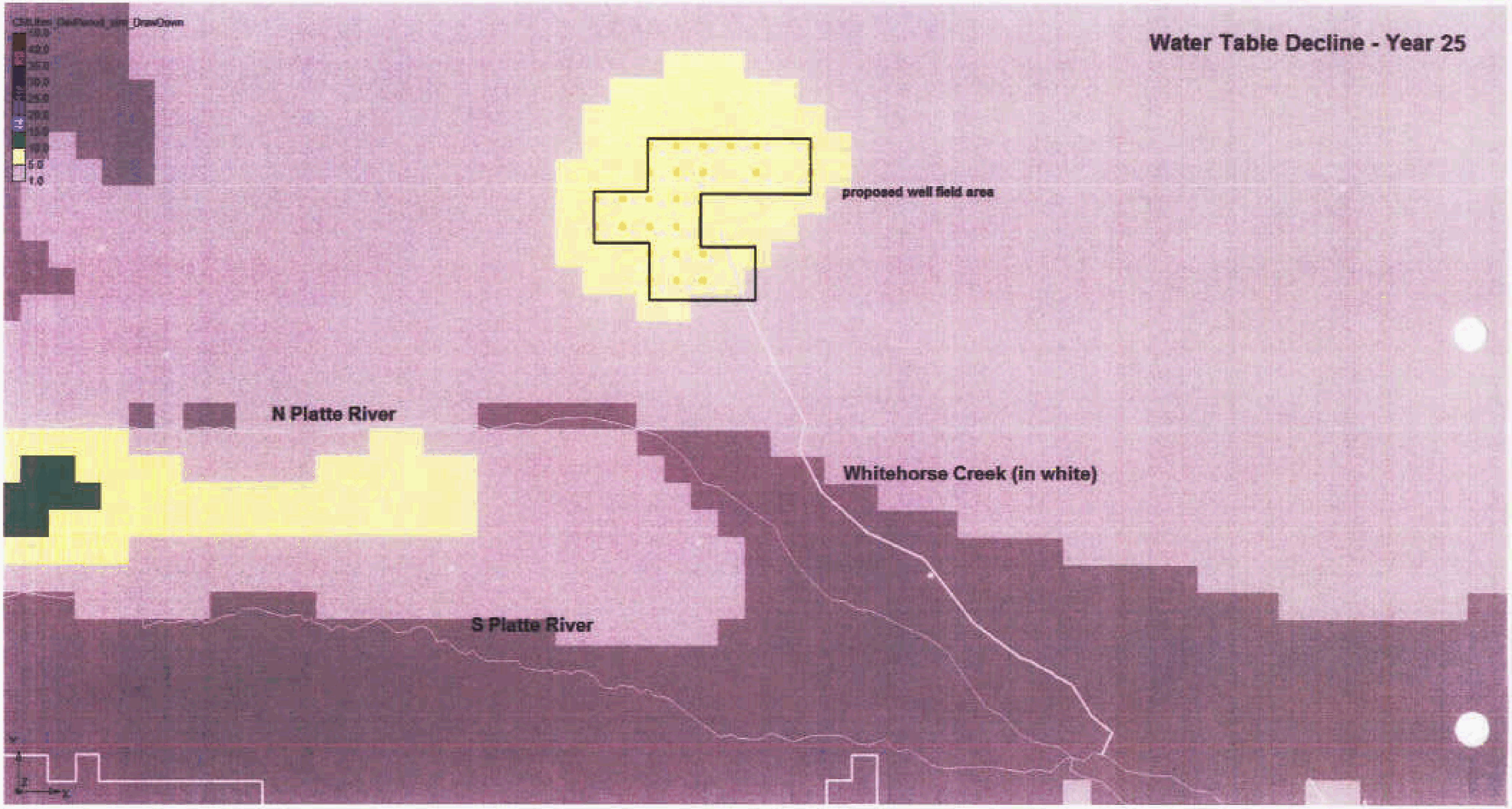

Figure 11. – Water table decline with the test irrigation well scenario at year 25. Color scaling in upper left corner of image.

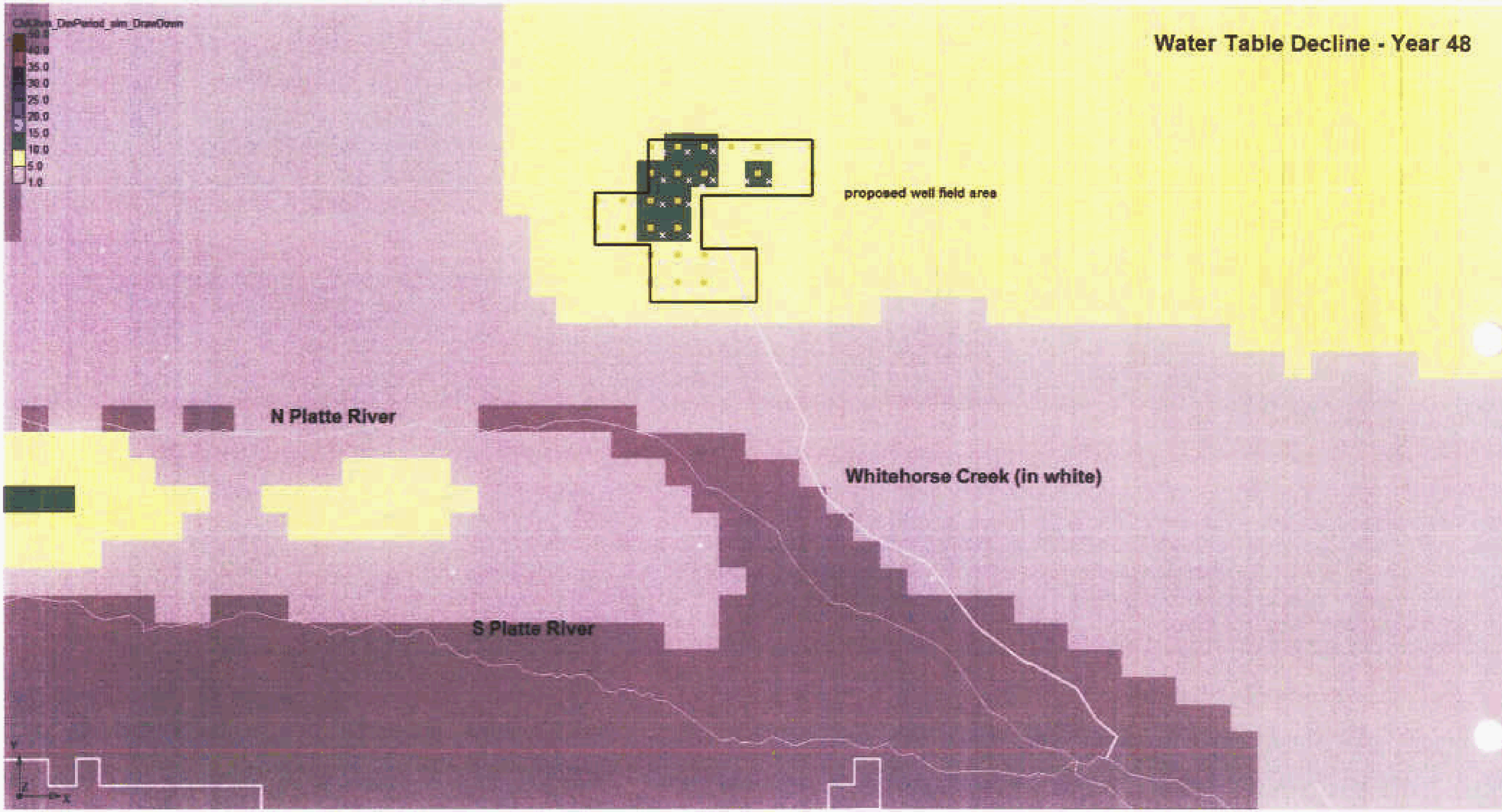

Figure 12. – Water table decline with the test irrigation well scenario at year 48. Color scaling in upper left corner of image.

Proposed Municipal Wells – Impacts with Variable Pumping Rates

For the simulation representing the proposed North Platte municipal well field pumping at variable rates, the following figures show the simulated water table elevations as well as the water level declines resulting from the well field pumping at years 5, 10, 25, and 48. The water table decline figures for years 5 and 10 at the end of the non-growing (or winter) stress period are included to show the slight change in water level declines with a reduced pumping rate. The actual well locations are marked with an x, whereas the simulated well location (centroid of the grid cell) is shown gold. Note that in the figures showing water level declines by color fill, the declines occurring to the southwest and northeast of the proposed well field area in the later stages of the pumping scenario are artifacts of the COHYST pumpage data sets where development occurred in the 1980s and 1990s. These areas of drawdown would occur with or without the proposed municipal wells simulated.

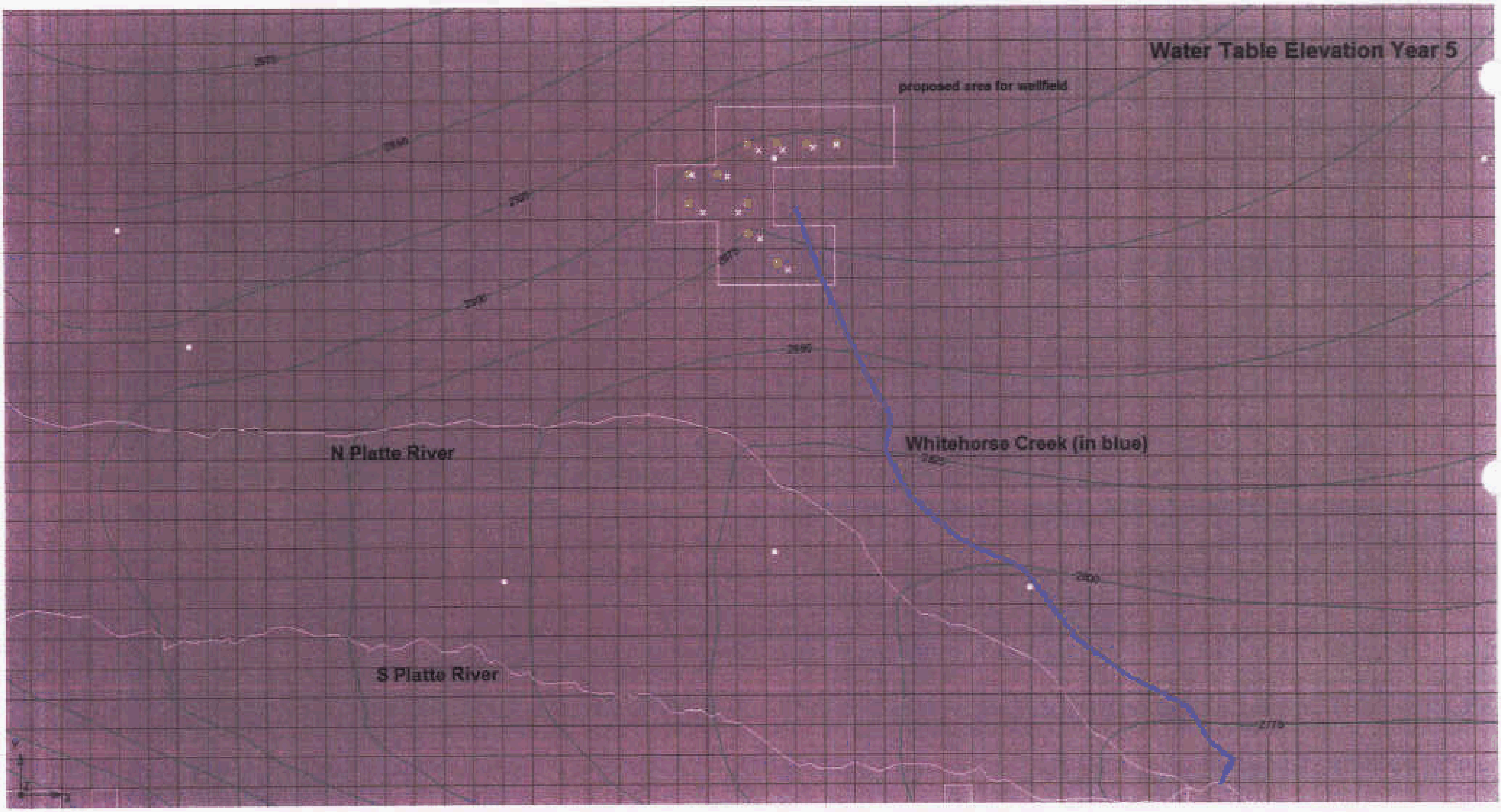

Figure 13. – Water table elevation with the 10 proposed municipal wells pumping at a variable rate for year 5.

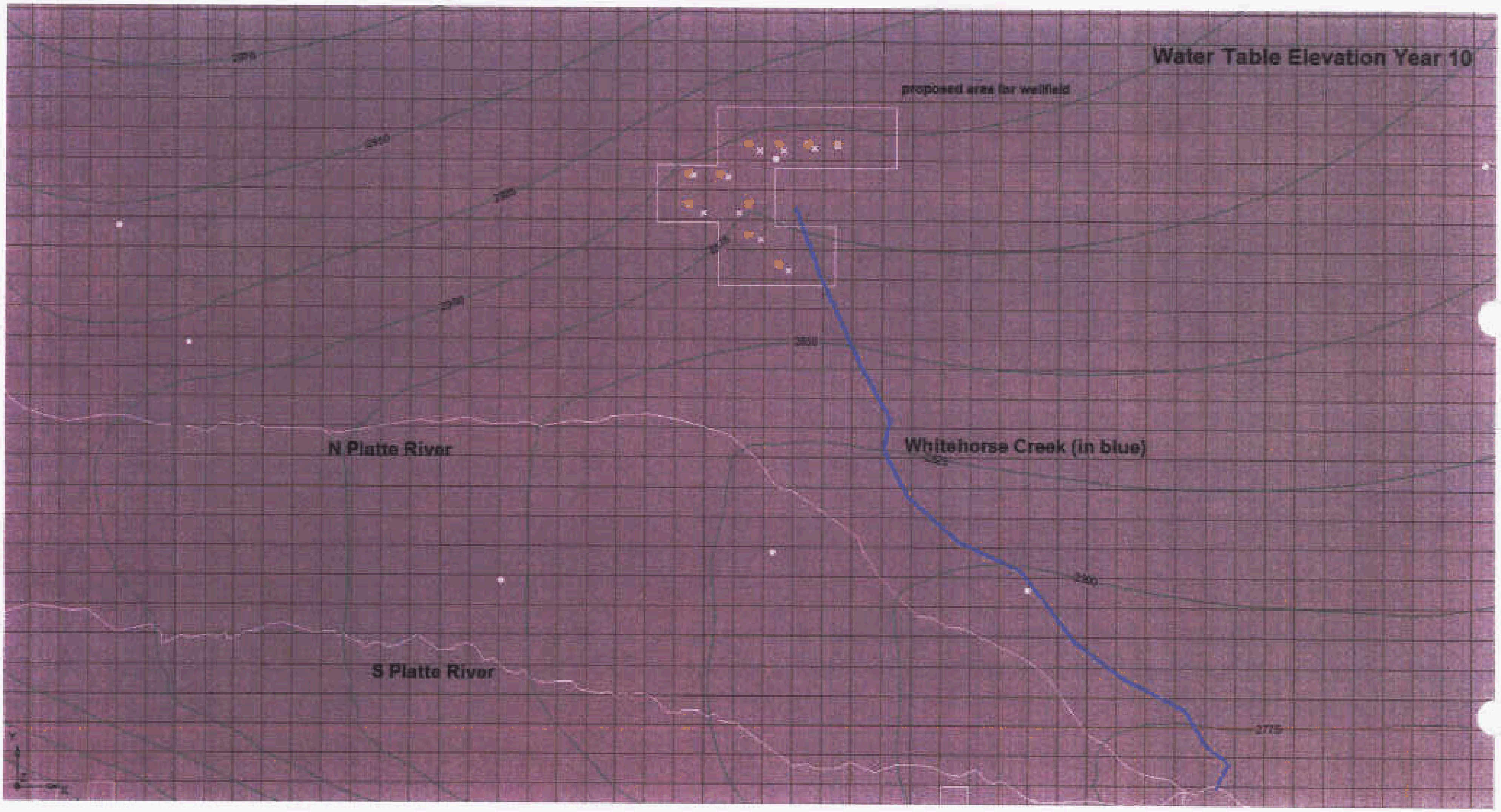

Figure 14. – Water table elevation with the 10 proposed municipal wells pumping at a variable rate for year 10.

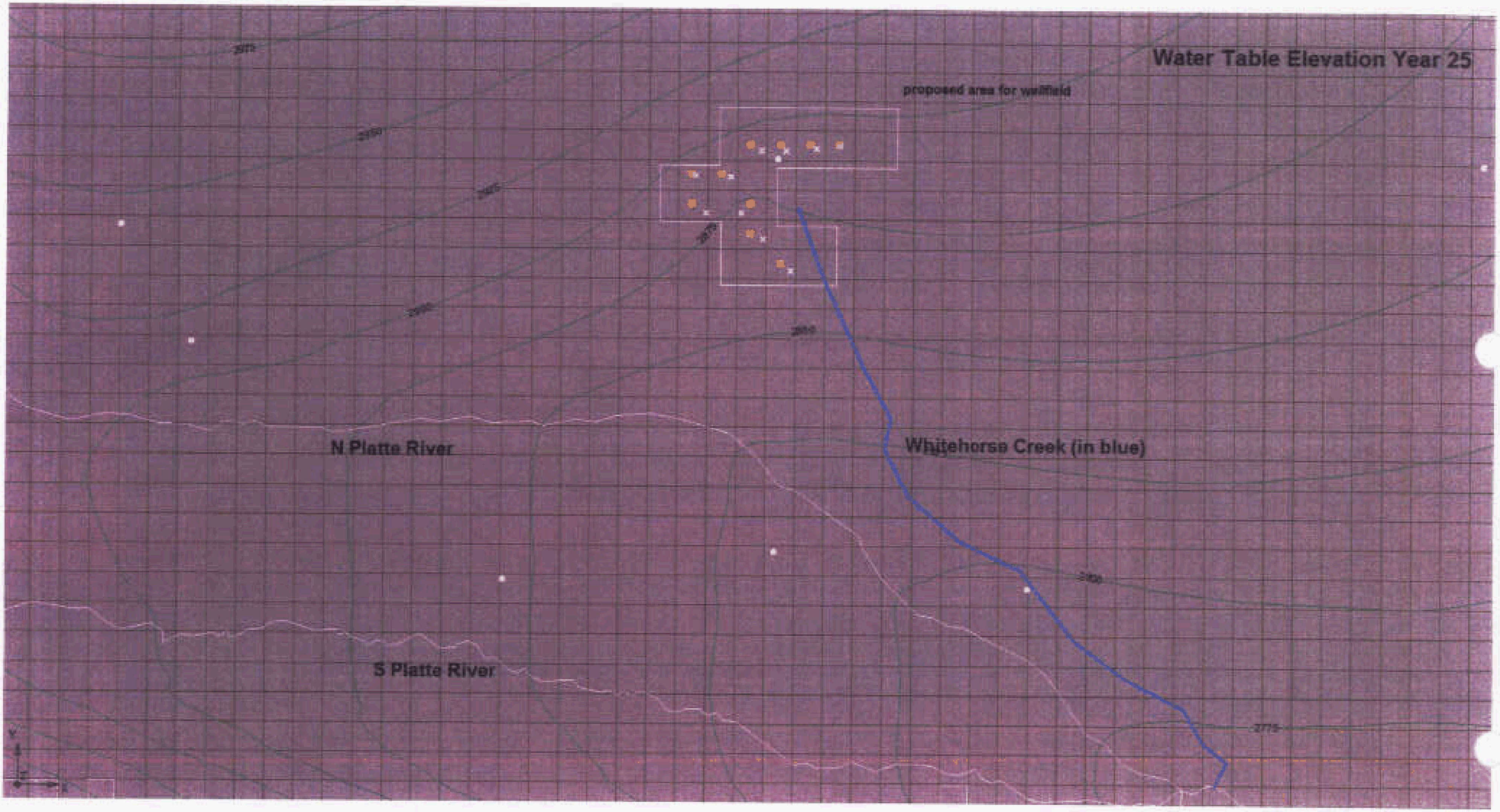

Figure 15. – Water table elevation with the 10 proposed municipal wells pumping at a variable rate for year 25.

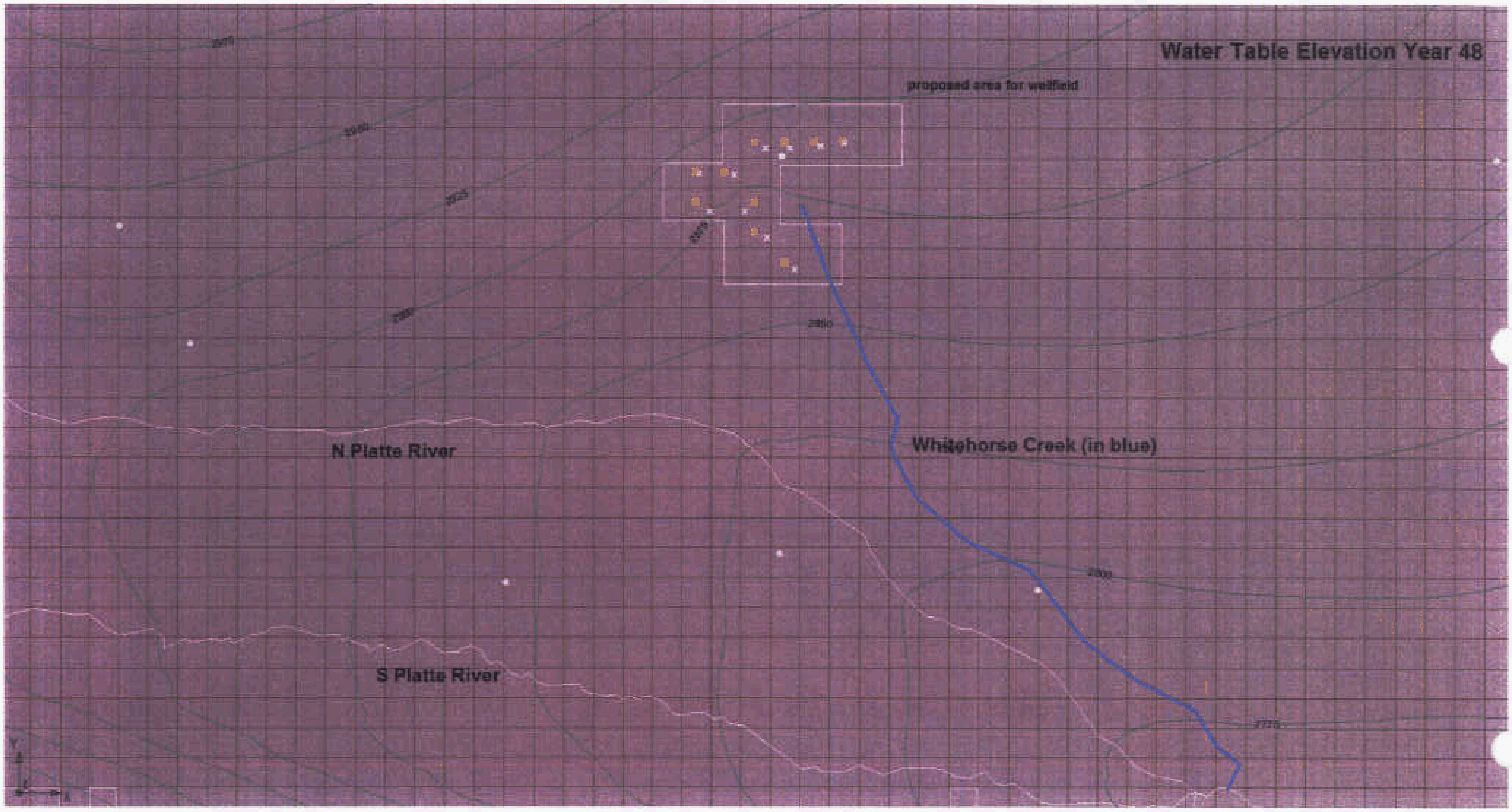

Figure 16. – Water table elevation with the 10 proposed municipal wells pumping at a variable rate for year 48.

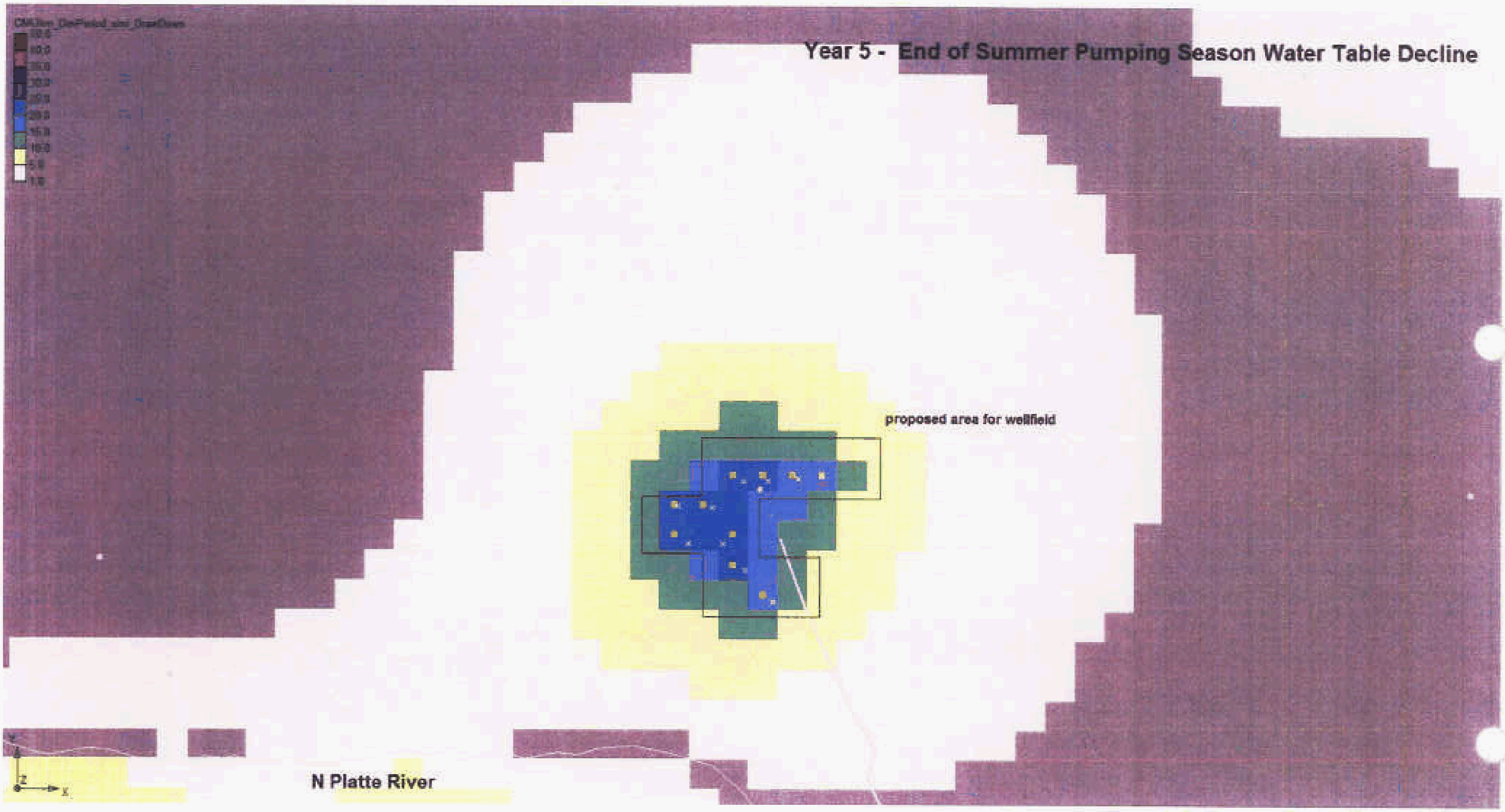

Figure 17. – Water table declines with the 10 proposed municipal wells pumping at a variable rate at the end of year 5 growing season. Note color scale in upper left part of figure.

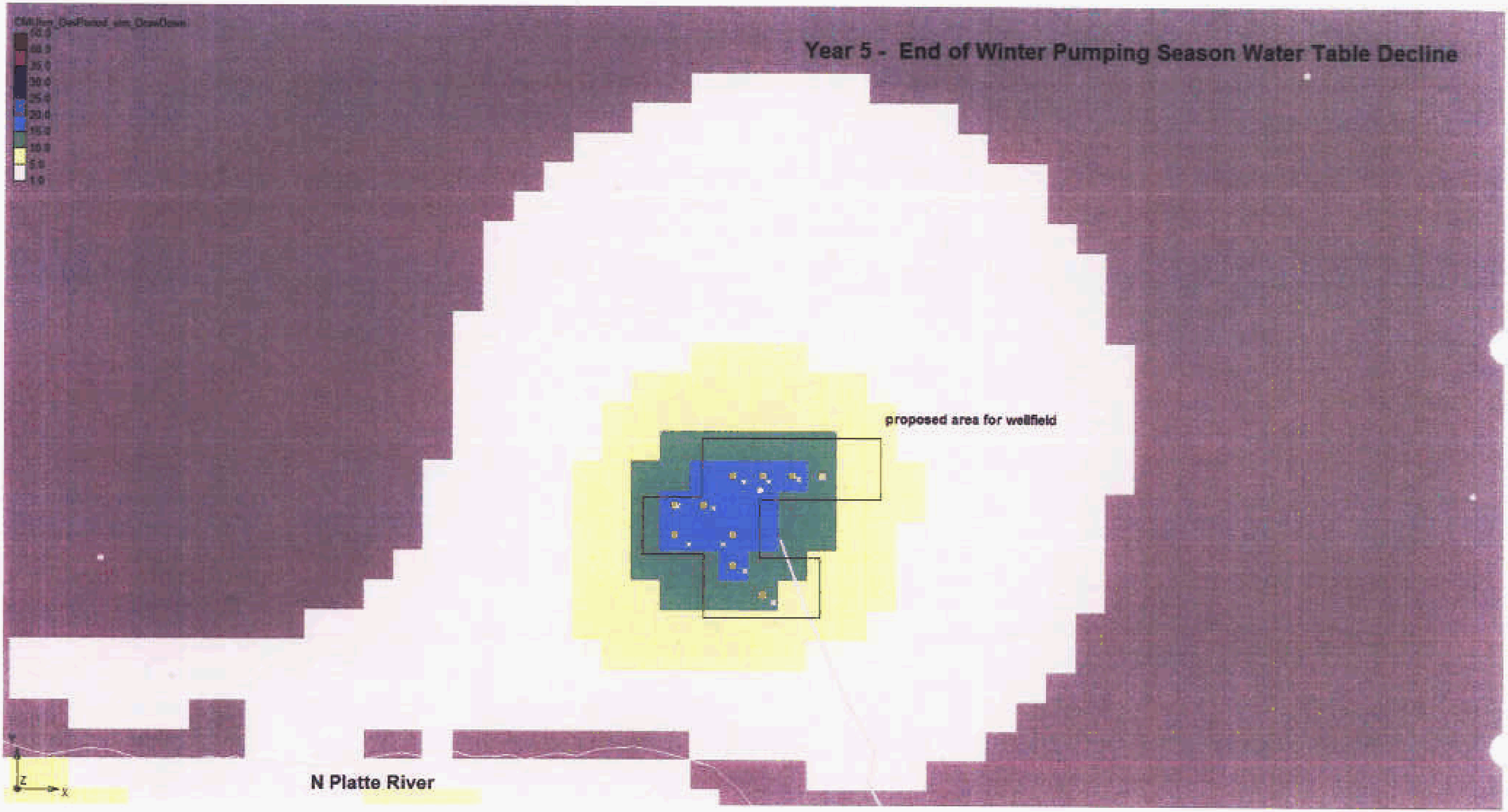

Figure 18. – Water table declines with the 10 proposed municipal wells pumping at a variable rate at the end of year 5 non-growing season. Note color scale in upper left part of figure.

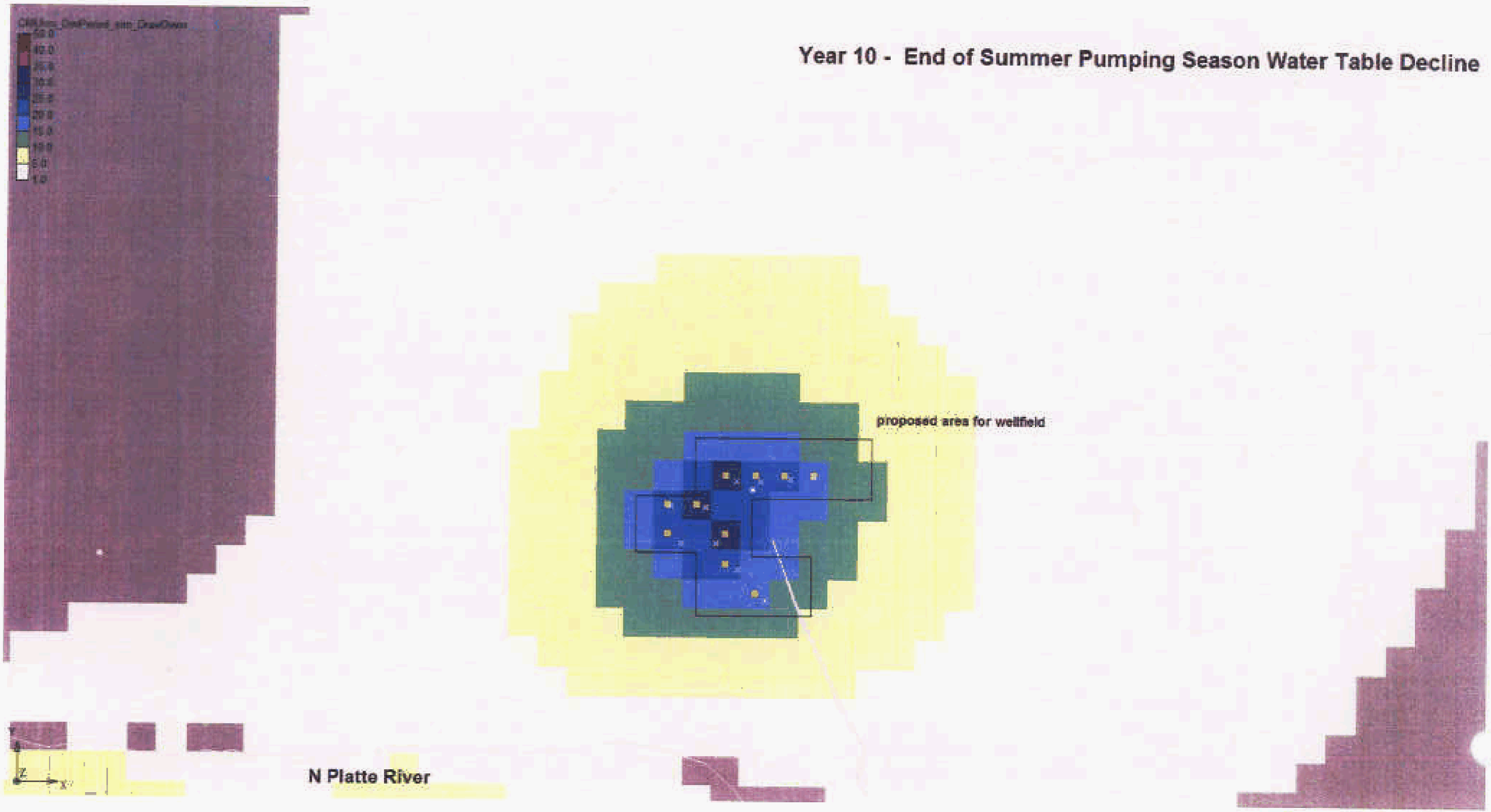

Figure 19. – Water table declines with the 10 proposed municipal wells pumping at a variable rate at the end of year 10 growing season. Note color scale in upper left part of figure.

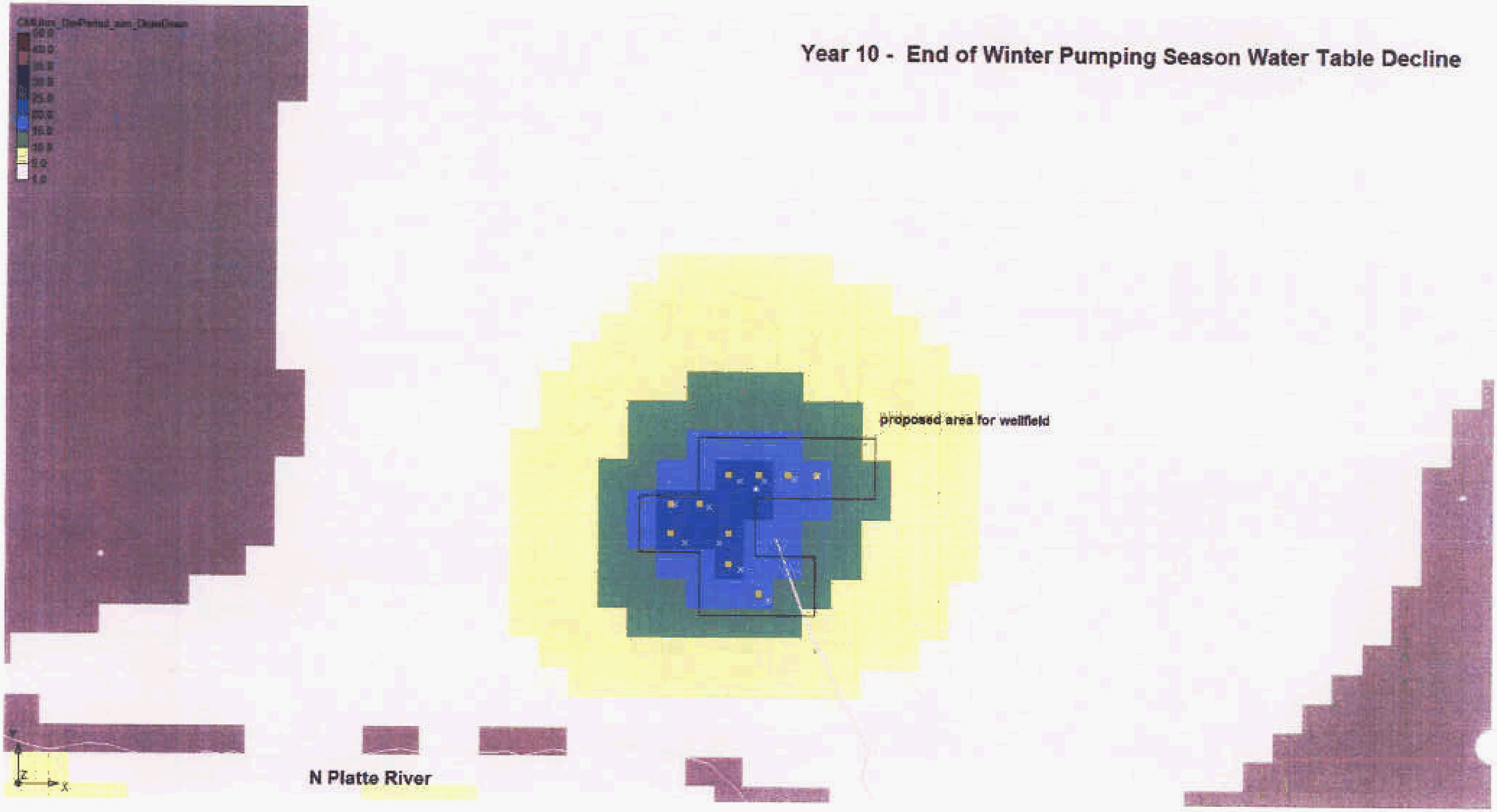

Figure 20. – Water table declines with the 10 proposed municipal wells pumping at a variable rate at the end of year 10 non-growing season. Note color scale in upper left part of figure.

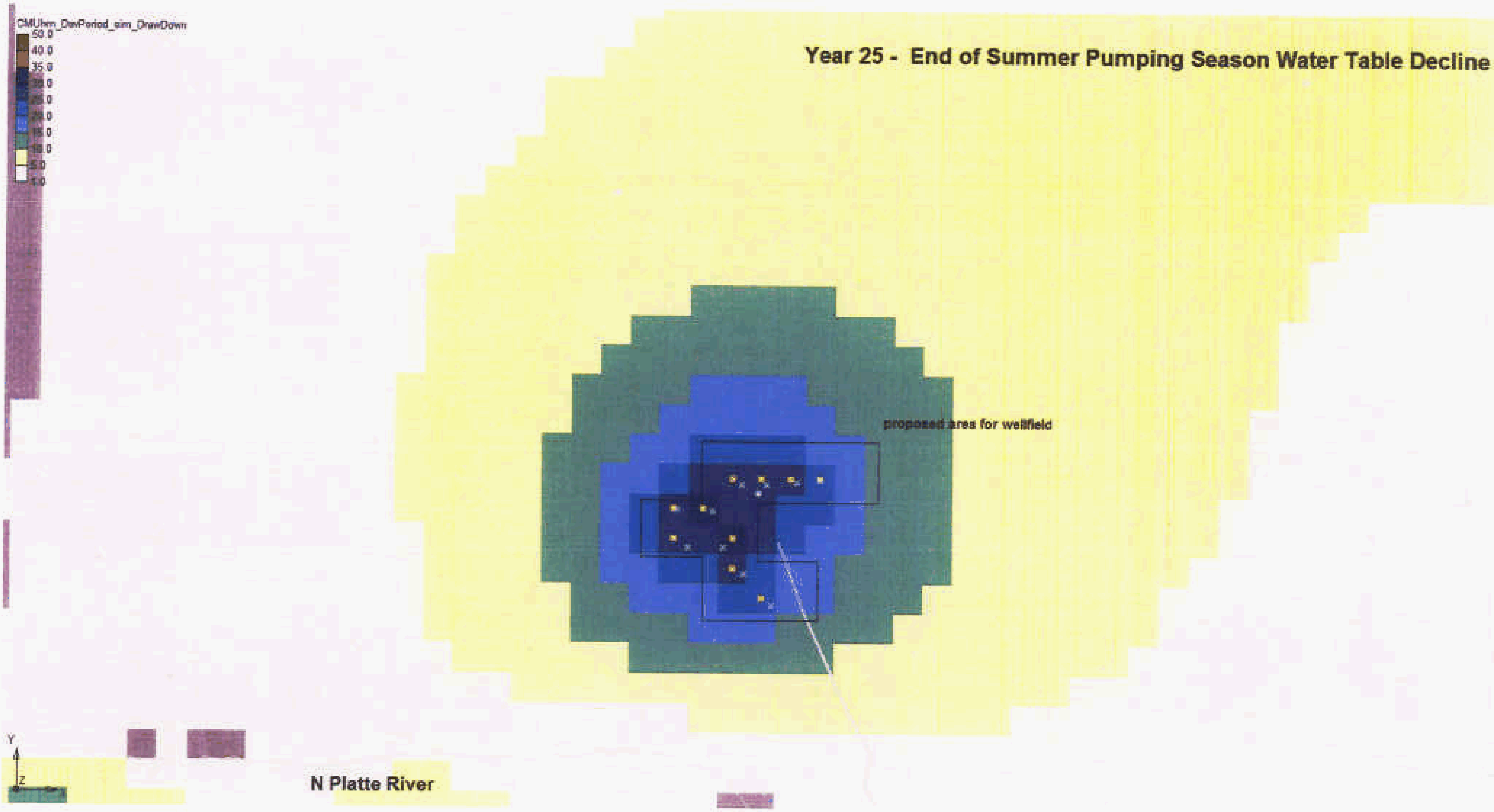

Figure 21. – Water table declines with the 10 proposed municipal wells pumping at a variable rate at the end of year 25 growing season. Note color scale in upper left part of the figure.

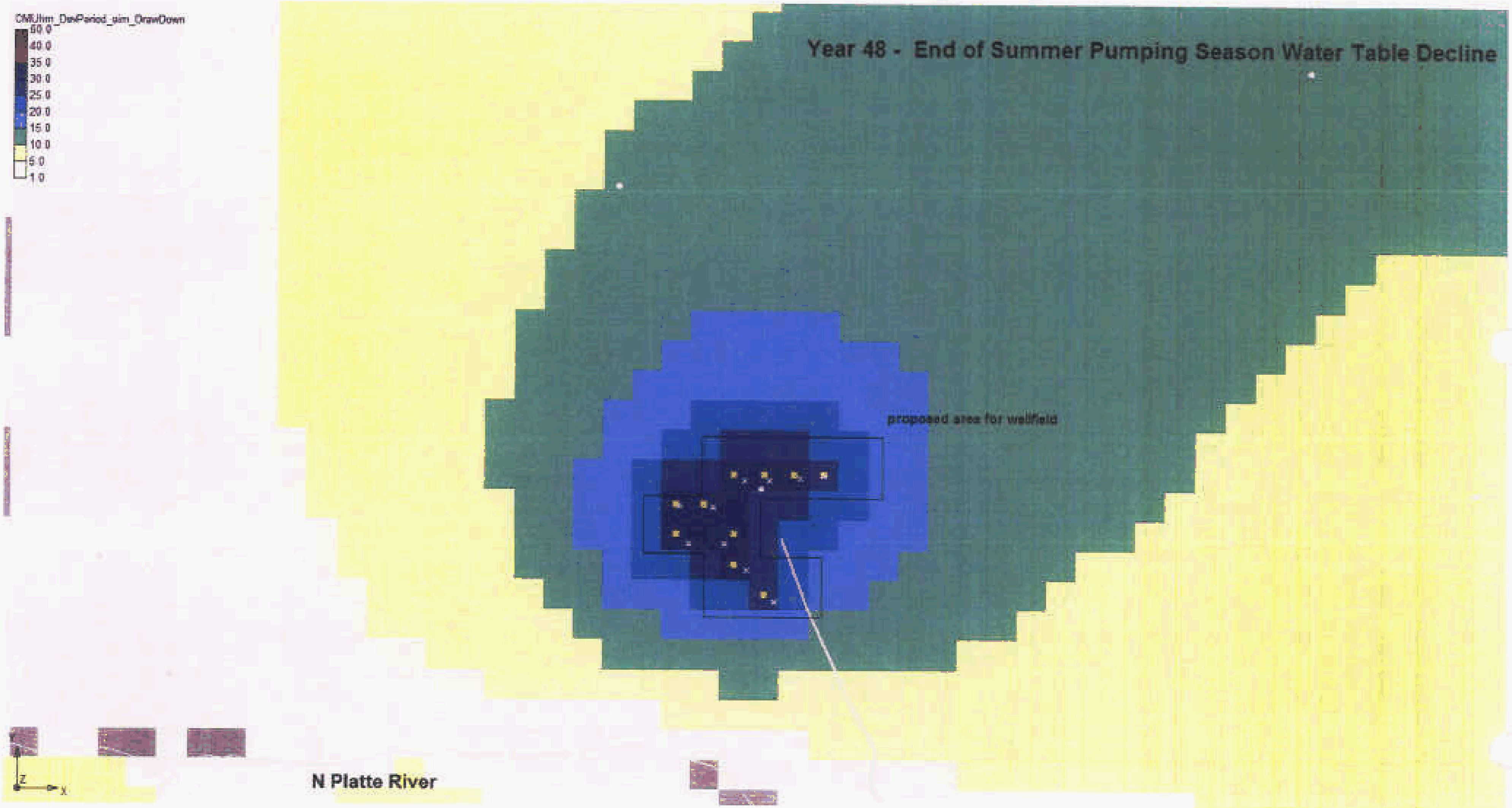

Figure 22. – Water table declines with the 10 proposed municipal wells pumping at a variable rate at the end of year 48 growing season. Note color scale in upper left part of figure.

Proposed Municipal Wells – Impacts with Average Pumping Rates

For the simulation representing the proposed North Platte well field pumping at variable rates, the following figures show the simulated water table elevations and the water level declines resulting from the well field pumping at year 5, 10, 25, 40, and 48. The actual well locations are marked with an x, whereas the simulated well location (centroid of the grid cell) is shown gold. Note that in the figures showing water level declines by color fill, the declines occurring to the southwest and northeast of the proposed well field area in the later stages of the pumping scenario are artifacts of the COHYST pumpage data sets where development occurred in the 1980s and 1990s. These areas of drawdown would occur with or without the proposed municipal wells simulated.

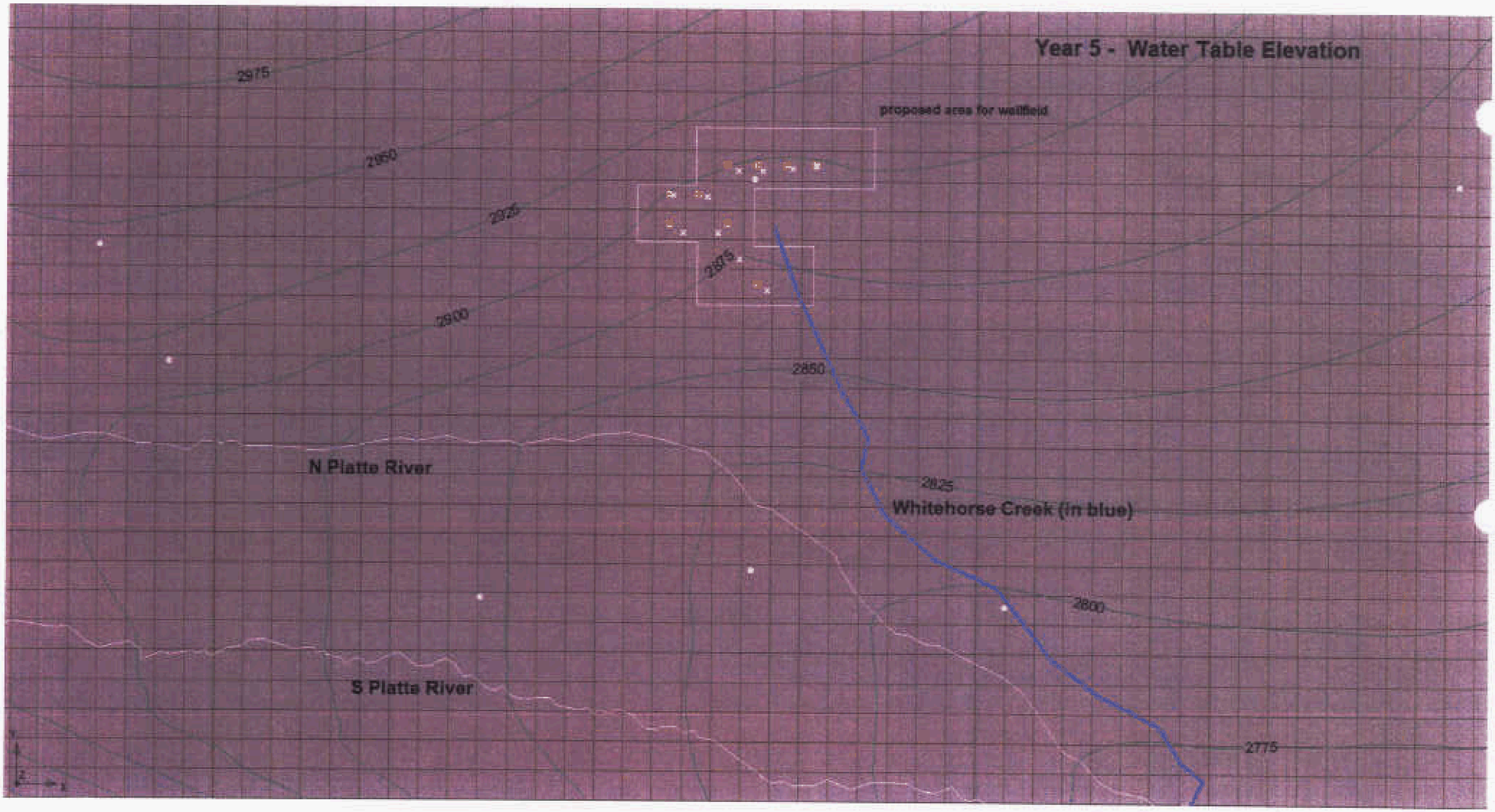

Figure 23. – Water table elevation with the 10 proposed wells pumping at an average rate for year 5.

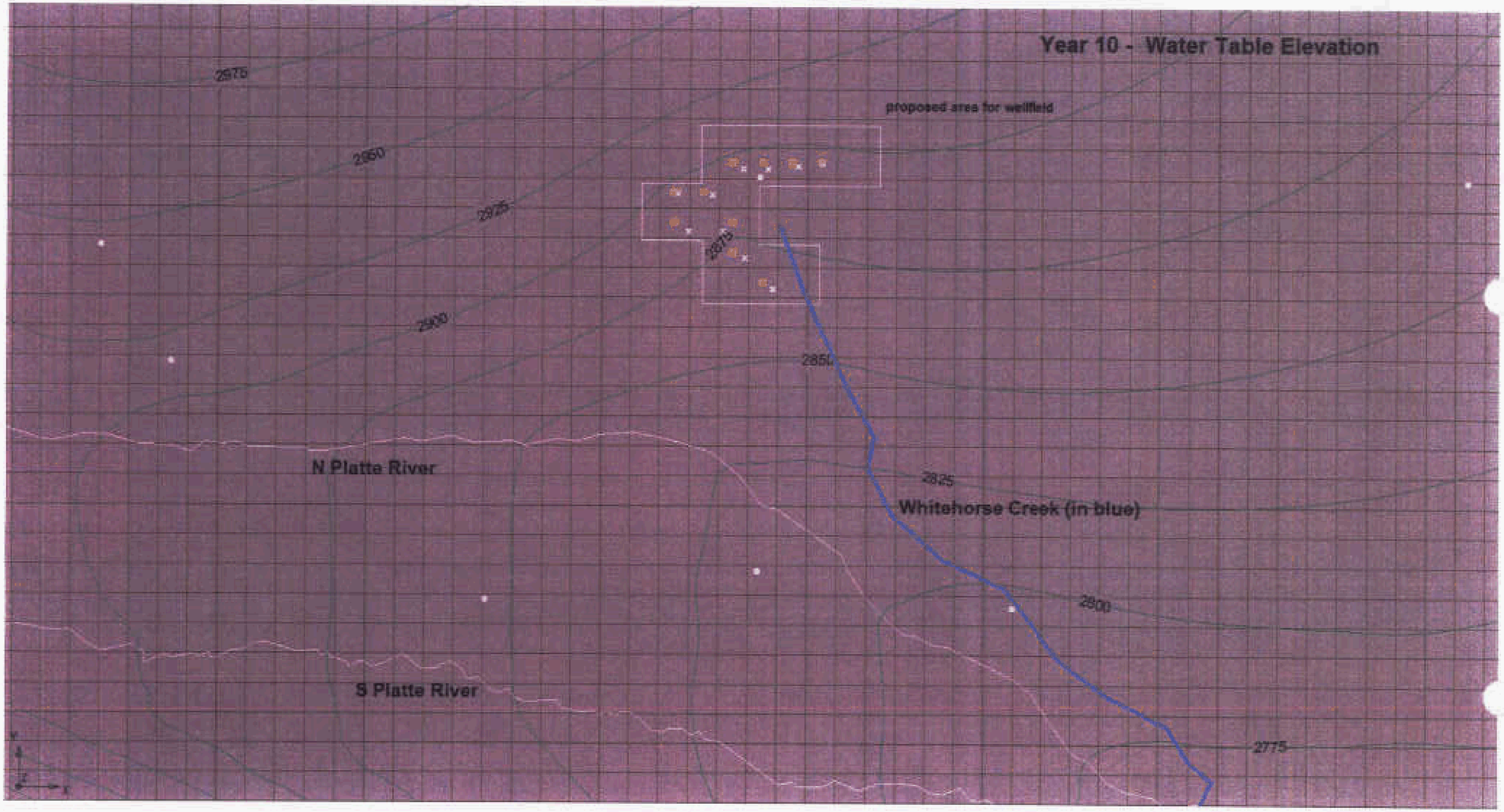

Figure 24. – Water table elevation with the 10 proposed wells pumping at an average rate for year 10.

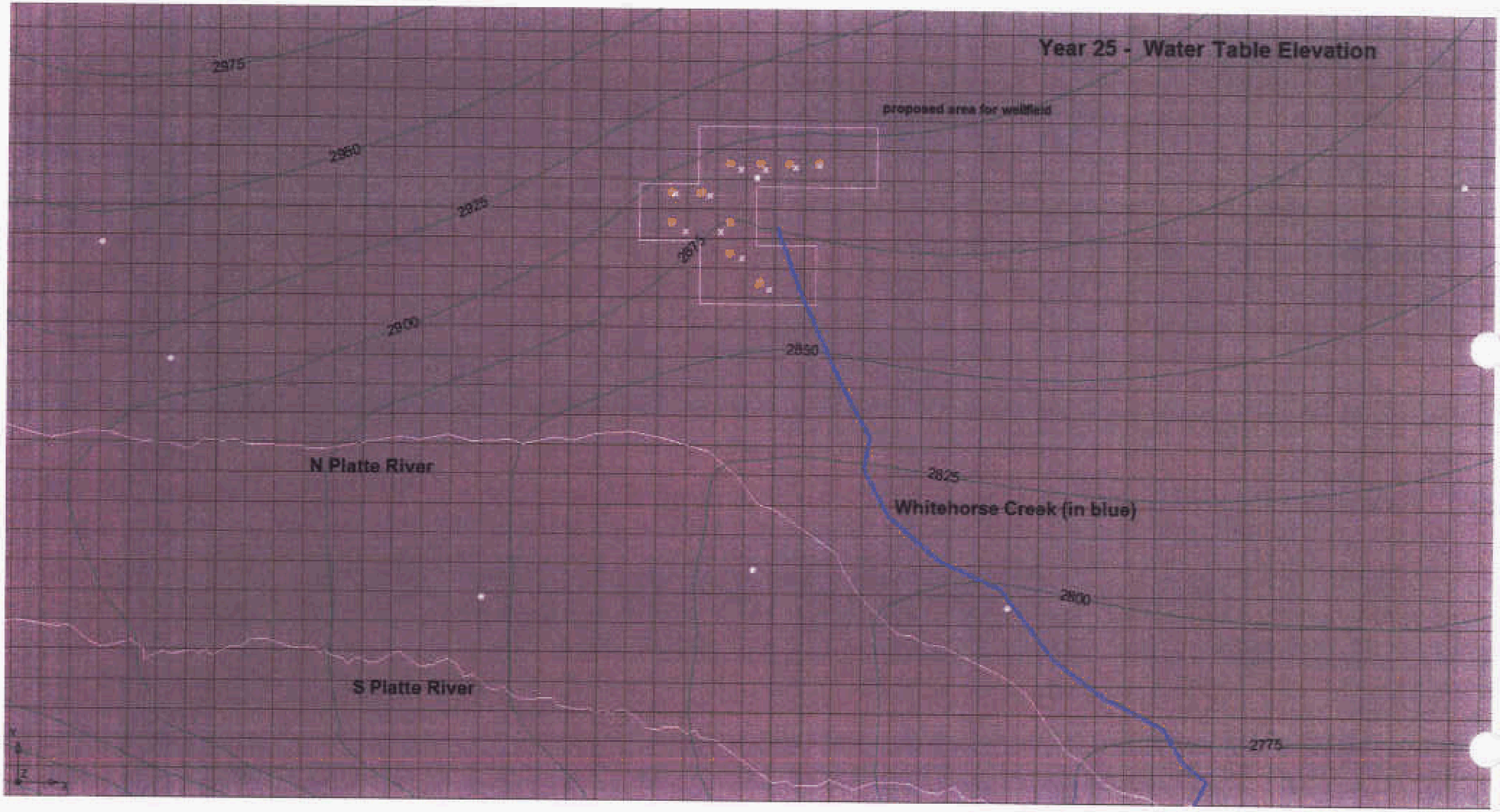

Figure 25. – Water table elevation with the 10 proposed wells pumping at an average rate for year 25.

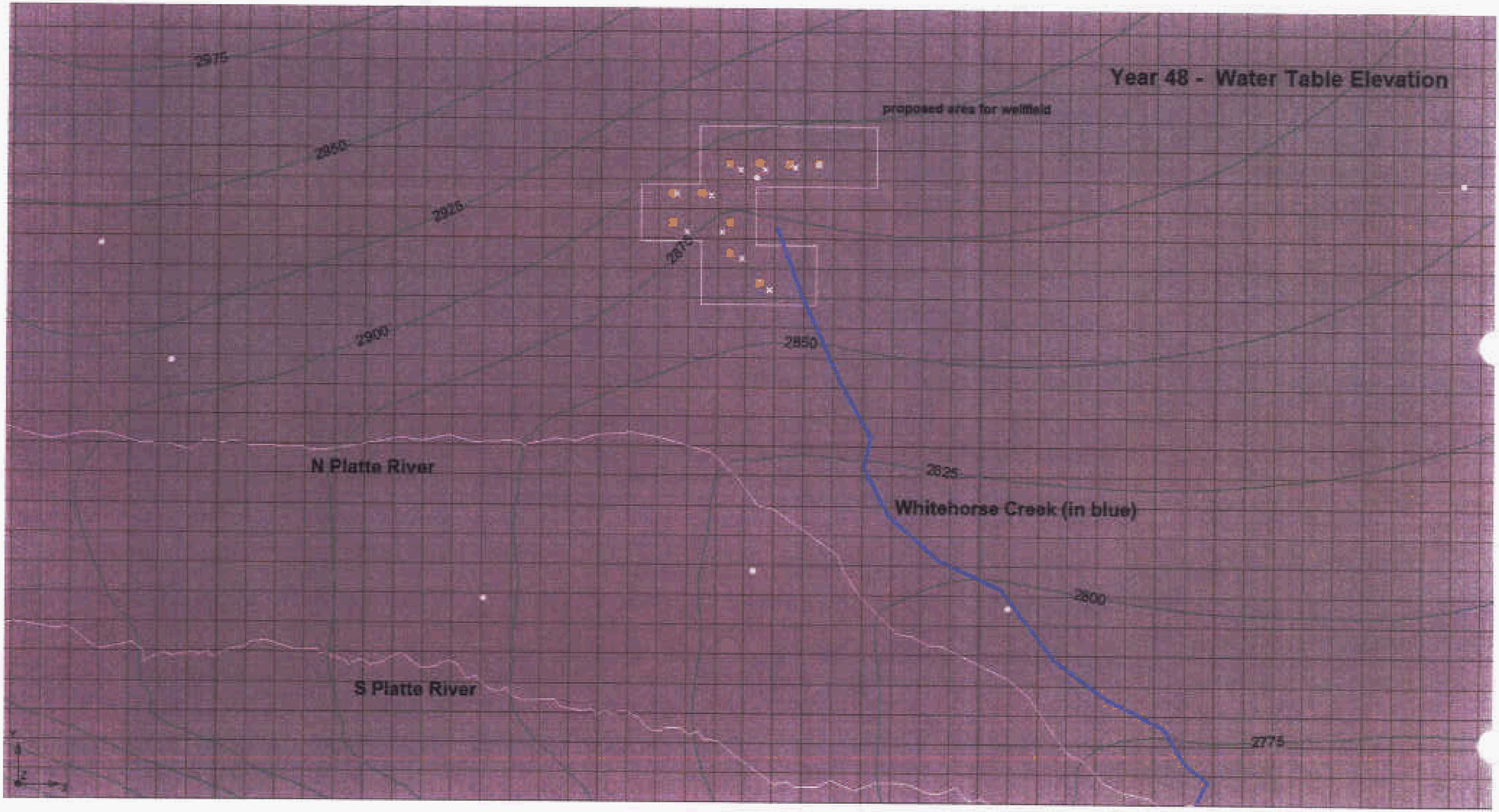

Figure 26. – Water table elevation with the 10 proposed wells pumping at an average rate for year 48.

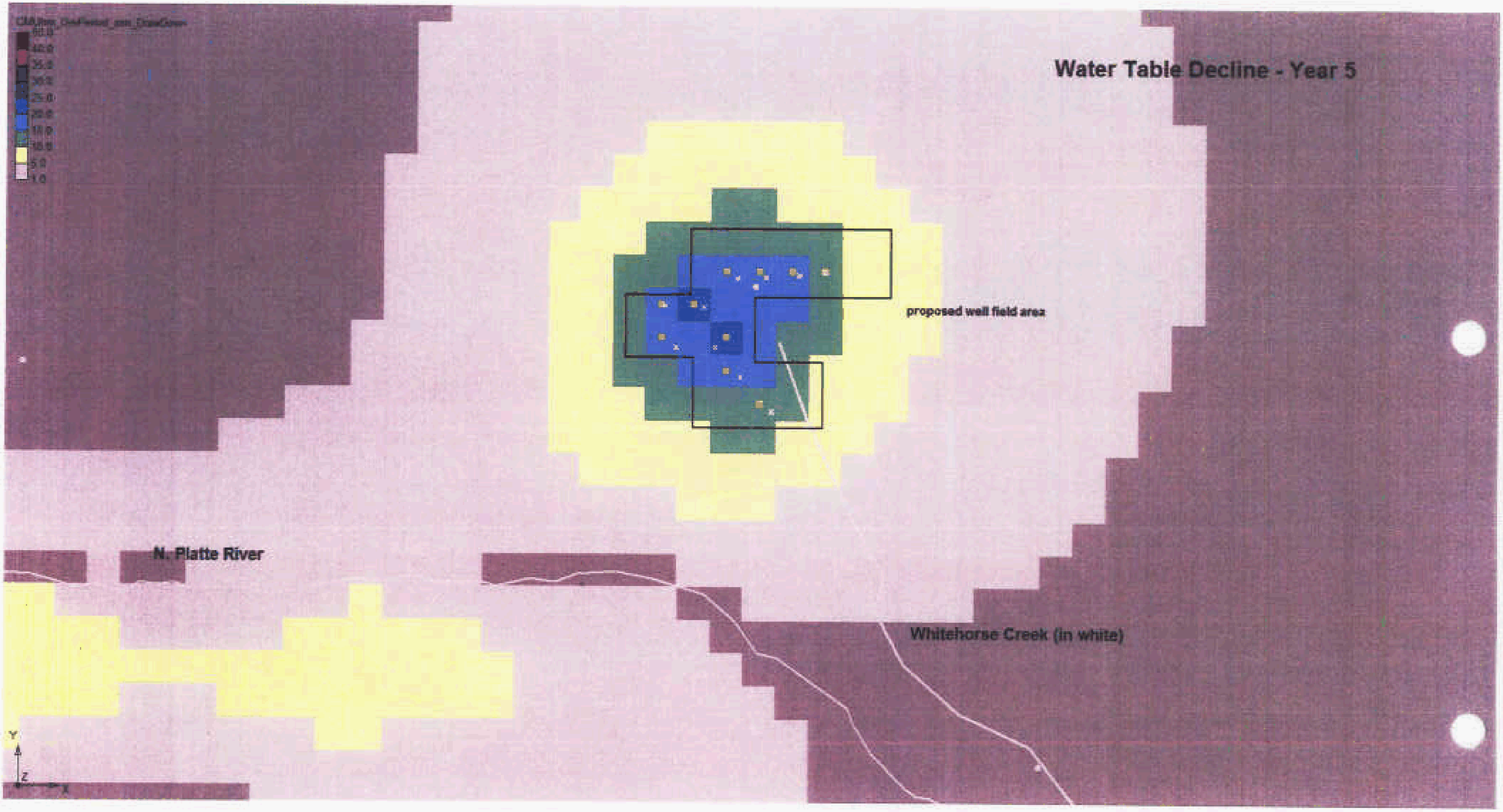

Figure 27. – Water table declines with the 10 proposed wells pumping at an average rate at the end of year 5 growing season. Note color scale in upper left part of figure.

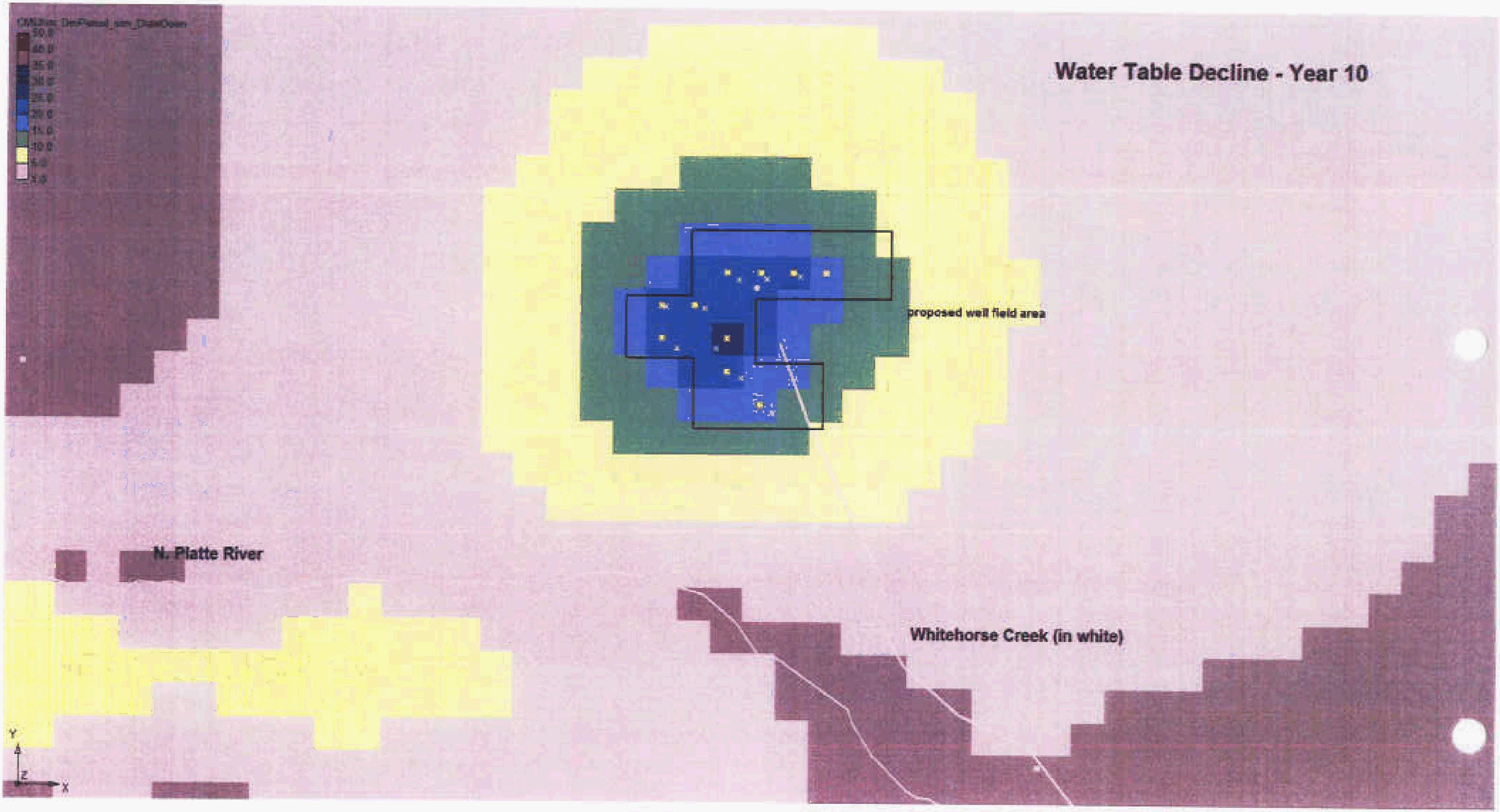

Figure 28. – Water table declines with the 10 proposed wells pumping at an average rate at the end of year 10 growing season. Note color scale in upper left part of figure.

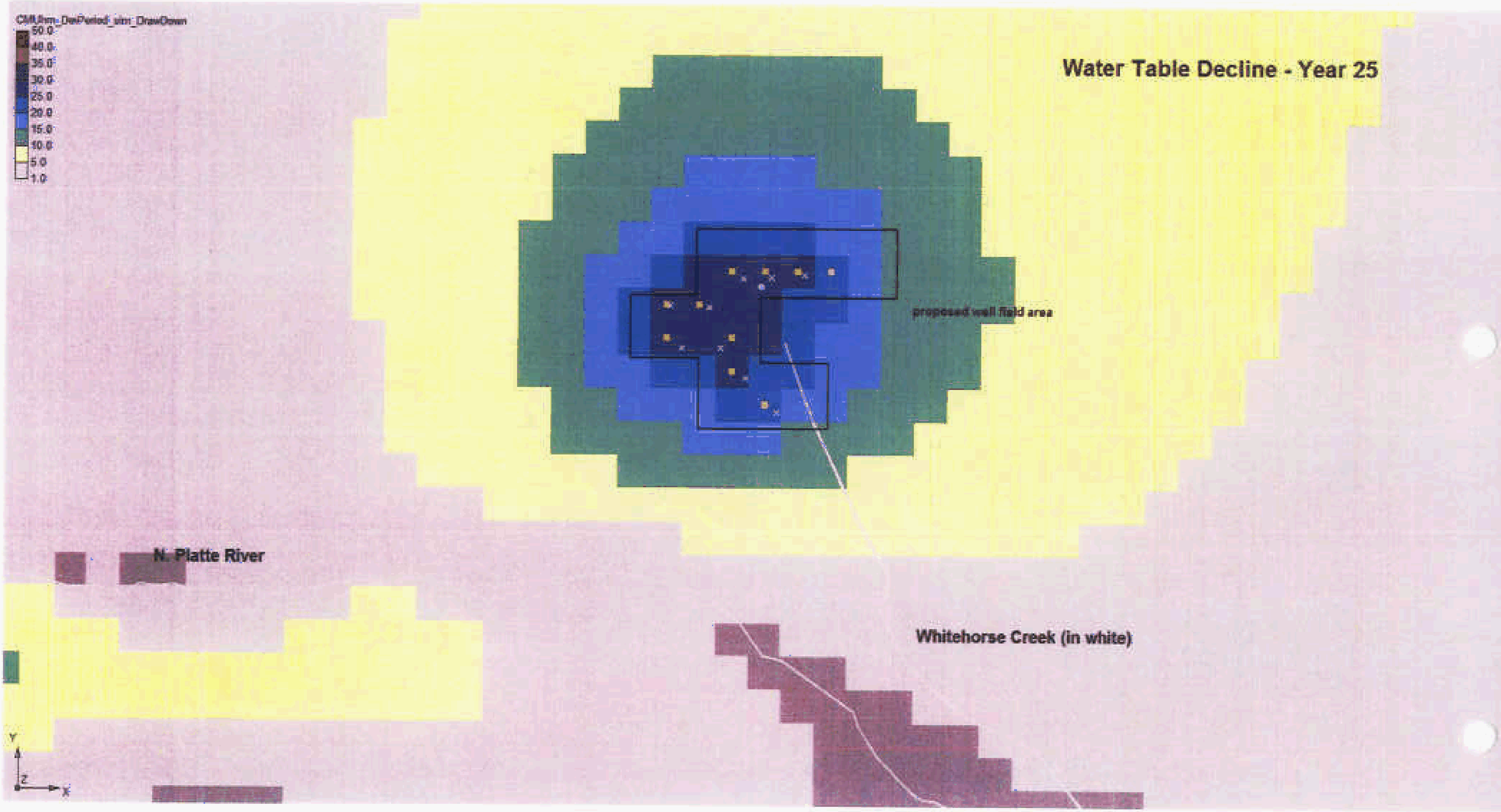

Figure 29. – Water table declines with the 10 proposed wells pumping at an average rate at the end of year 25 growing season. Note color scale in upper left part of figure.

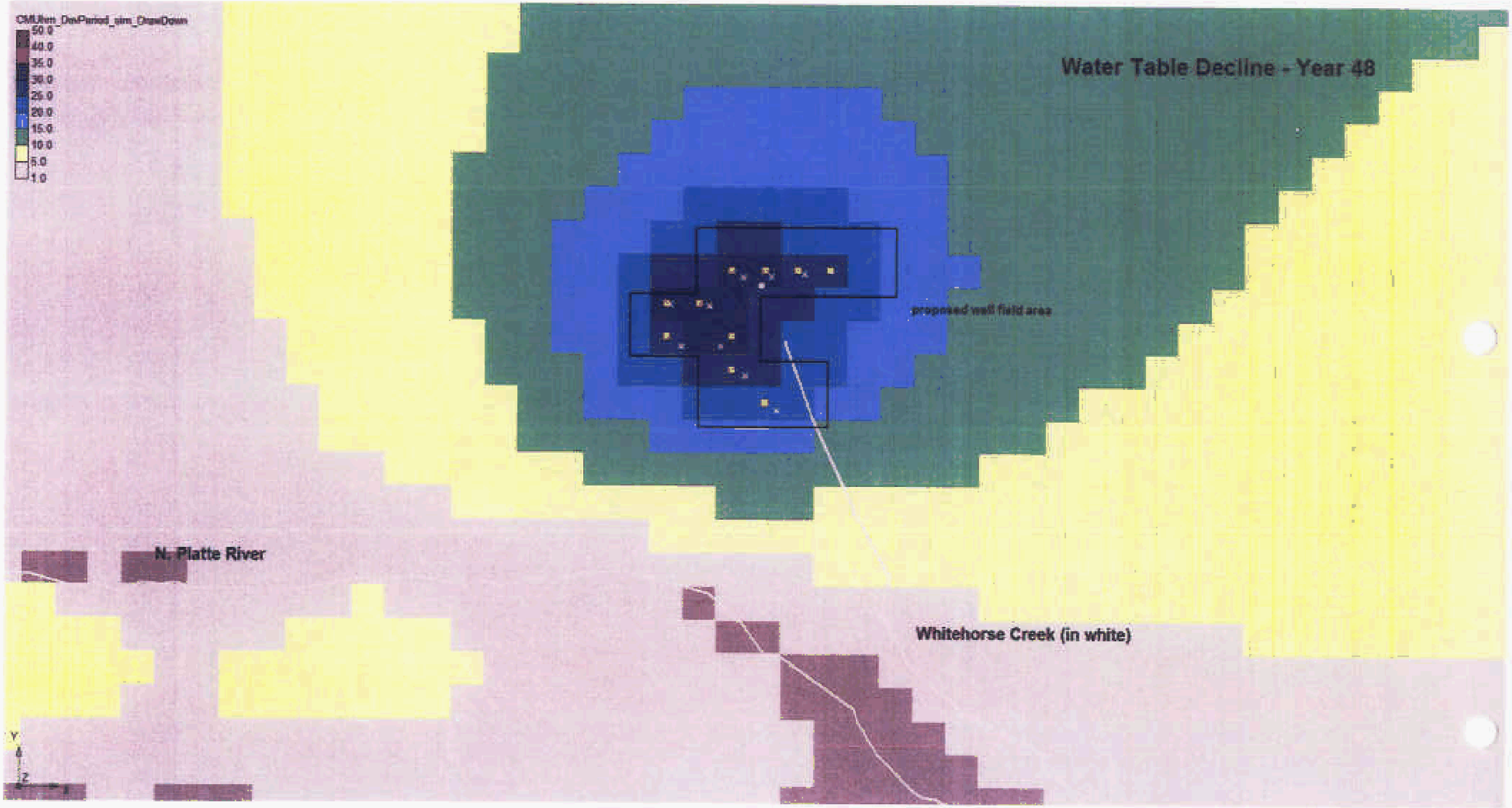

Figure 30. – Water table declines with the 10 proposed wells pumping at an average rate at the end of year 48 growing season. Note color scale in upper left part of figure.

Long Term Impacts

Each simulation was run for 48 years to provide long-term predictions to the High Plains aquifer and aquifer discharge to Whitehorse Creek. For the variable pumping scenario, a remaining saturated thickness map was produced (fig. 31) to determine the long-term impacts of pumping the proposed North Platte well field. The map shows contours representing the percent of remaining saturated thickness at year 48. Near the center of the well field, a 91 percent contour covers a small area. This indicates that in the center of the well field, the overall saturated thickness was reduced by nearly 10 percent by year 48 of the variable-rate pumping scenario. Note that the scale effects of the model cell size may not capture individual cones of depression around each well, some of which could be deeper than indicated in the water level decline figures. The amount of drawdown indicated in these maps seems reasonable as the proposed well field is located in a regional discharge zone based on regional water table maps and previous modeling studies.

The Whitehorse Creek discharge chart (fig. 32) indicates the long-term decrease in aquifer discharge to Whitehorse Creek for each pumping scenario described in this report. The proposed well field pumping scenarios produced analogous results with a decrease in discharge by just over 1 cfs in the 48 year timeframe. The presence of a relatively thick unit of fine material in the upper portion of the Ogallala Group (above the screened zones of the wells) likely restricts the immediate influence of the wells on Whitehorse Creek.

Summary

The results from the simulations described in this report for the impacts to Whitehorse Creek and the High Plains aquifer from the proposed North Platte well field indicate that water table declines approaching 40 feet in the well field area could be expected after 25 years of pumping, and that smaller less declines (5-15 feet) could be expected to propagate from the well field area as the well field is used over the next 50 years. The impacts to Whitehorse Creek approach 1.1 cfs after nearly 50 years of pumping. The most rapid decline in the aquifer discharge to Whitehorse Creek occurs in the first 25 years of the well field operation. During the next 25 years, the rate of decline lessens, but still continues in a trend of decreased baseflow to the stream. It should be emphasized that the current pumping rates for North Platte municipal wells are approximately 60% of what is simulated in either the temporal or average pumping rate scenarios, and that the results provided in this report indicate worst case scenario responses of the groundwater/surface water system.

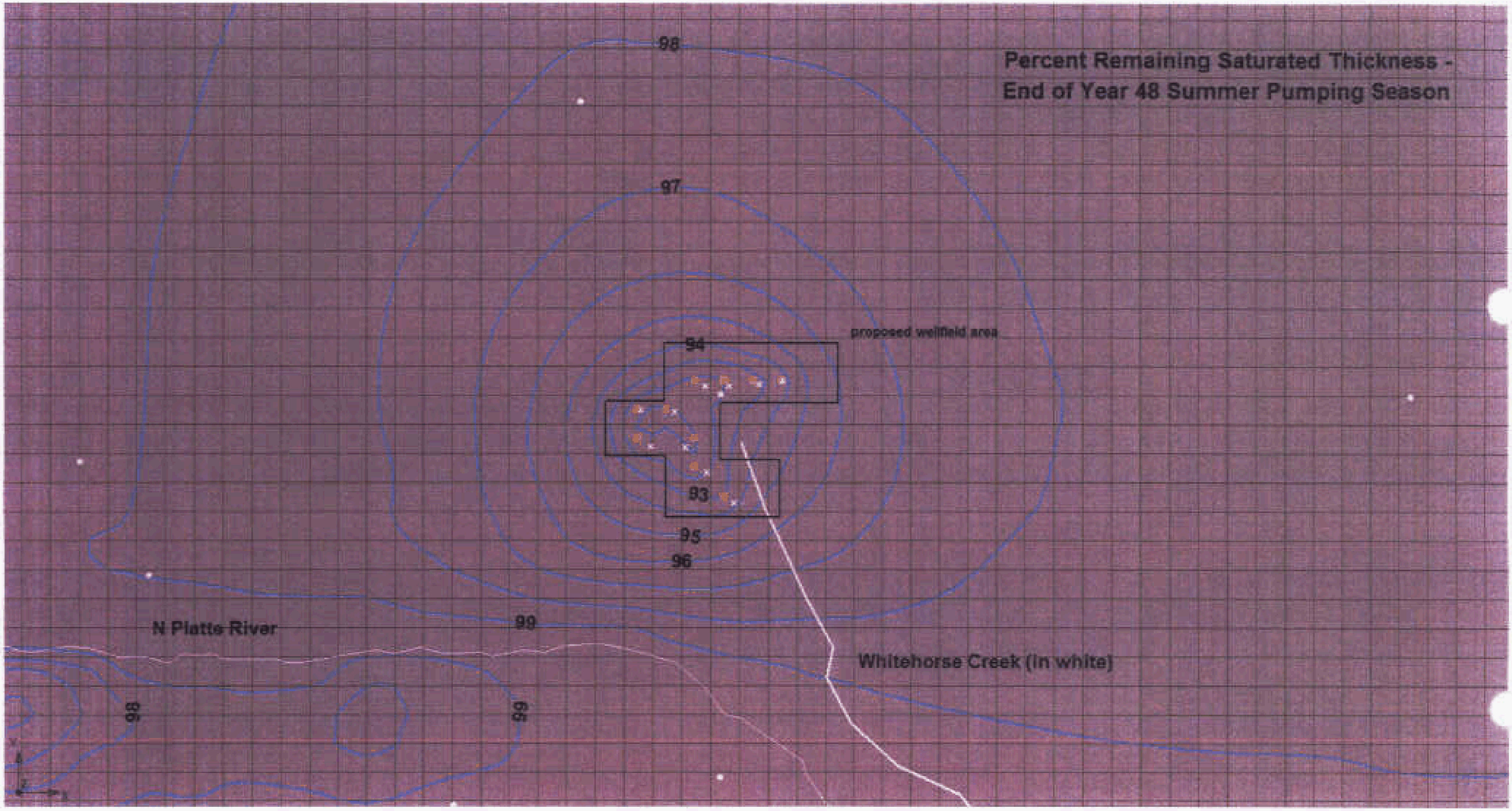

Figure 31. – Percent of saturated thickness remaining in aquifer at end of the 48-year variable pumping rate scenario.

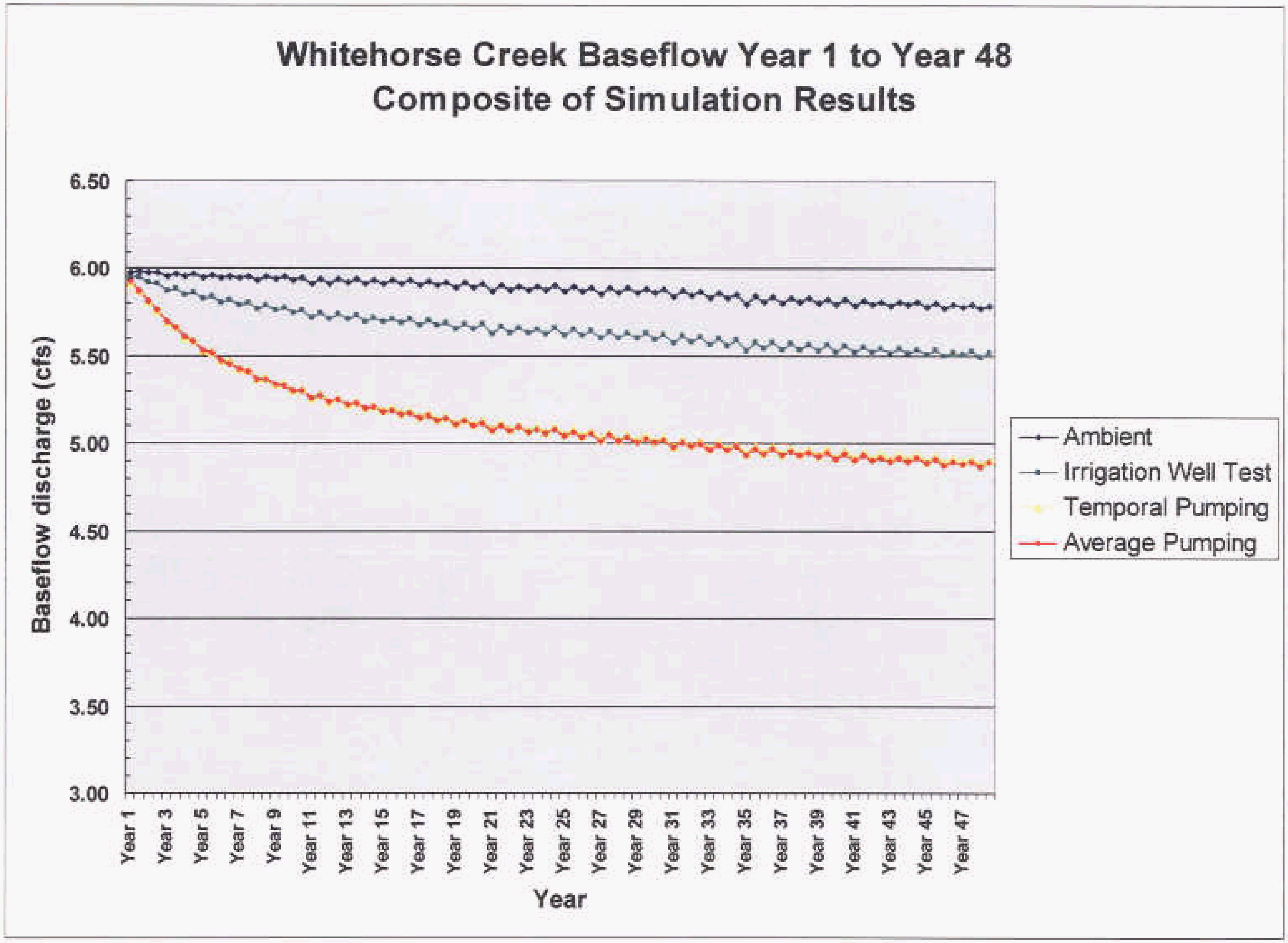

Figure 32. – Graph of long-term impacts to Whitehorse Creek for each 48-year pumping scenario. Note that the average and variable well field pumping rates overly one another (gold and red).

References

Carney, C.P., and Peterson, S.M., 2001. Estimated Groundwater Discharge to Streams from the High Plains Aquifer In the Central Model Unit of the COHYST Study Area for the Period Prior to Major Groundwater Irrigation. Available at http://cohyst.dnr.state.ne.us/adobe/dc012CMU_baseflw_01.pdf

Klocke, N.L., Hubbard, K.E., Kranz, W.L., and Watts, D.G., 1990, Evapotranspiration (ET) or Crop Water Use: Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln NebGuide G90-992, 4 p.

APPENDIX

Pumping Rates Provided by Miller and Associates

City of North Platte
Historical Pumping by Month

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	system Totals
1999	153,388,000	118,069,000	122,028,000	143,585,000	184,209,000	305,144,000	313,574,000	321,722,000	210,614,000	173,535,000	178,052,000	118,466,000	2,342,386,000
2000	151,701,000	115,923,000	117,199,000	254,978,000	250,029,000	347,688,000	358,378,000	340,235,000	278,151,000	204,075,000	113,838,000	150,133,000	2,682,324,000
2001	113,438,000	112,925,000	112,055,000	163,967,000	208,948,000	336,687,000	358,457,000	277,863,000	284,660,000	149,145,000	134,785,000	143,286,000	2,396,216,000
2002	112,764,000	114,839,000	116,805,000	220,457,000	217,778,000	441,705,000	411,942,000	340,976,000	257,938,000	205,821,000	114,078,000	143,935,000	2,699,036,000
2003	119,830,000	112,192,000	122,947,000	166,787,000	160,678,000	202,032,000	407,519,000	325,530,000	353,729,000	236,574,000	110,195,000	141,309,000	2,459,322,000
2004	124,298,000	121,329,000	159,111,000	177,444,000	237,887,000	284,964,000	246,703,000	244,268,000	295,837,000	151,403,000	123,528,000	134,015,000	2,302,567,000
2005	110,738,000	106,952,000	129,155,000	125,945,000	174,806,000	247,036,000	300,057,000	325,960,000	280,843,000	159,824,000			
AVERAGE	**126,593,857**	**114,604,143**	**125,614,286**	**179,023,000**	**204,873,571**	**309,322,286**	**342,661,429**	**310,939,571**	**277,367,429**	**182,911,000**	**129,078,667**	**138,524,000**	**2,480,308,500**
GPM	2,836	2,842	2,814	4,144	4,589	7,160	7,676	6,965	6,421	4,097	2,988	3,103	4,719
Future pumpage	4,481	4,491	4,446	6,548	7,251	11,313	12,128	11,005	10,144	6,474	4,721	4,903	7,456

Calculations for pumpage rates:

Future	Summer average rate:	10,369	gpm
	10,369	1,996,032.50	cu ft/d
		305,392,972.50	total cu ft for months highligl
		1,996,032.50	cu ft/d
		199,603.25	per well (10)
	Non pumping season rate	5151.8	gpm
	5152	991,722	cu ft/d
		210,244,958.00	total cu ft for time period
		991,721.50	cu ft/d
		99,172.15	per well (10)
Current	Summer average rate:	6,562	gpm
	6,562	1,263,185.00	cu ft/d
		193,267,305.00	total cu ft for months highligl
		1,263,185.00	cu ft/d
		126,318.50	per well (10)
	Non pumping season rate	3260.6	gpm
	3261	627,666	cu ft/d
		133,065,086.00	total cu ft for time period
		627,665.50	cu ft/d
		62,766.55	per well (10)

Average Annuals

Current	908,408.27	cu ft/d rate
	331,569,018.23	entire year volume cu ft
	908,408.27	cu ft/d
	90,840.83	per well (10)
Future	1,435,285.07	cu ft/d rate
	523,879,048.80	entire year volume cu ft
	1,435,285.07	cu ft/d
	143,528.51	per well (10)