ATTACHMENT 12
Shadow Flicker Analysis

Subject: Initial Shadow-Flicker Modeling Results, Kittitas Valley Wind Power Project, WA.

Customer: Zilkha Renewable Energy
210 SW Morrison, Suite 310
Portland, OR 97204

Prepared by: Arne Nielsen, Wind Engineers, Inc.

Revision: 1

Date: Apr. 20, 2003

1. Introduction

This Project Briefing explains in layman's terms what shadow-flicker is. The briefing also contains a summary of the shadow-flicker modeling results for the KVWPP and relevant explanations to the attached shadow-flicker reports.

Wind Engineers Inc. (WEI) has visited the site for the purposes of creating visual simulations and we are familiar with the general area and the general terrain within and around the Project area.

Shadow flicker caused by wind turbines is defined as alternating changes in light intensity due to the moving blade shadows cast on the ground and objects (including windows at residences). Consequently, shadow-flicker is not:

a) the sun seen through rotating wind turbine blades
b) moving through the shadows of a wind farm (driving)

Also, if there are any kind of obstacles such as terrain, trees, buildings etc. between the wind turbine and a potential shadow-flicker receptor, then shadow-flicker is either significantly reduced or eliminated at such receptors.

The shadow-flicker frequency is related to the rotor speed and number of blades on the rotor. The modeling results presented in this report are based on the NEG-Micon wind turbine with a 72-meter rotor diameter and a nominal rotor speed of 17.3 RPM which translates to a blade pass frequency of 0.87 Hz (less than 1 alternation per second).

Health wise, such low frequencies are harmless. Frequencies higher than 3 Hz but below 10 Hz are widely used in discotheques and the Epilepsy Foundation has made a statement that frequencies below 10 Hz are not likely to trigger epilepsy seizures.

A very important aspect of shadow-flicker that is often not known or not discussed is the intensity of the flicker.

1. The wind turbine blade is widest close to the nacelle/hub and narrower towards the blade tip. If a wind turbine is located close to a shadow-flicker receptor then the blade roots (the portion of the blade closest to the hub) might be wide enough to cover the sun's disk entirely. This increases the flicker intensity. A wind turbine further away will only cover a slice of the sun's disk and the intensity will therefore be reduced.
2. As the flickering shadow cast by the wind turbine rotor moves through the receptor area, the intensity change and the greatest intensity will be when the cast shadow of the nacelle/hub hits the shadow-receptor.
3. In high visibility conditions, the intensity will be slightly higher than in low visibility and fog.
4. Another aspect of the intensity is that the cast shadow is far more "in focus" when the wind turbine is close to the receptor. When the wind turbine is further away the flickering is less distinct.

The above four aspects are not directly addressed in the shadow-flicker model – only flicker or no flicker is reported. Consequently, marginally affected receptors are likely not to experience shadow-flicker at all even though the report tables and plots indicate shadow-flicker time and marginally affected receptors will experience little flickering in terms of intensity. In other words, the shadow flicker model OVERESTIMATES that intensity of the flicker impacts.

2. The Shadow-Flicker Model

The shadow-flicker model used for this analysis is produced by EMD of Denmark and is part of the WindPro modeling software package. It requires the following inputs:

1. Turbine locations
2. Shadow flicker receptor locations
3. USGS 1:24,000 topo map
4. USGS DEM (height contours)
5. Rotor diameter
6. Hub height
7. Joint wind speed and direction distribution
8. Hours of sunshine (monthly averages)

The model calculates the shadow-flicker time for either a) each receptor b) everywhere (defined squares) or both (a and b). A receptor is defined as a window at a residence. Azimuth of windows has been estimated for each residence (East, West or 90, 180, 270 degrees from the nearby access road) and the default window size is assumed to be 1 by 1 meter. The sun's path is calculated from the turbine location and the cast shadow derived over the day. Then the run-time for the turbine is derived from the wind data (speed and direction). This is important because when the turbines are not operating (such as when the wind speed is too low) there is no shadow flicker.

When the wind direction is perpendicular to the direction of the wind turbine (as seen from the receptor) then the shadow-flicker time is reduced drastically in that the cast shadow is narrow, whereas when the wind direction is in line with the direction of the turbine (as seen from the receptor) then the full rotor plane shadow needs to pass the receptor. Cloudiness is also considered in the model (no direct sun means no shadow).

Output from the model:
Usually a map with contour lines showing the number of hours of shadow-flicker per year is most useful. The output is:

9. Turbine locations and elevations
10. Calculated shadow-flicker time at selected receptors
11. Tabulated and plotted time of day with shadow flicker at selected receptors
12. Listing of turbines causing shadow flicker at each selected receptor
13. Map showing turbine locations, selected shadow-flicker receptors and line contours indicating projected shadow-flicker time (hours per year).

3. Results

Wind turbine names and shadow-flicker receptors have been named according to Project lay-out maps provided by Zilkha Renewable Energy. Only shadow-flicker receptors (houses) in the immediate vicinity of turbines have been included in the model, as those more distant houses will not be affected. Shadow-flicker receptors to the north or south of wind turbines are not likely to receive shadow-flicker, because the cast shadow is very short in the north and south directions, as can be seen in the shape of the contour lines on the accompanying reports.

Several reports are attached. Each report shows the results of the shadow-flicker model in each selected area. The areas are about 1 x 1 mile squares. The receptors (houses) that were selected for this analysis are those that represent the potential worst case scenarios. Based on their locations relative to the proposed turbines, these are the receptors where the greatest shadow flicker impacts are expected. One report (030420 Kittitas shadow-flicker, all turbines.pdf) shows the contour lines for the entire project area. From this report it can be seen that the worst case shadow-flicker receptors have been selected.

Highest modeled shadow-flicker level is 83 hours per year at receptor T Gerean (058W) the next highest is 45 hours at receptor Nelson (417E). T Gerean will experience the shadow-flicker in the evening only if windows are present to the west and Nelson will experience shadow-flicker both morning and evening if windows are present to the east and west. The duration is between 8 and 40 minutes on days that shadow-flicker is present.

4. Attachments

1. 030416 Kittitas shadow-flicker, 117 Geisick.pdf	6 pages
2. 030418 Kittitas shadow-flicker, 058 T Gerean and 59 L Gerean.pdf	8 pages

3. 030418 Kittitas shadow-flicker, 080 Price and 215 Schwab.pdf	7 pages
4. 030418 Kittitas shadow-flicker, 417 Nelson.pdf	8 pages
5. 030419 Kittitas shadow-flicker, 043 Anthony and 044 Gaskill.pdf	8 pages
6. 030419 Kittitas shadow-flicker, 045 Taylor.pdf	7 pages
7. 030419 Kittitas shadow-flicker, 048 Zellmer, 082 M Campbel….pdf	11 pages
8. 030420 Kittitas shadow-flicker, 047-118 Pearson.pdf	6 pages
9. 030420 Kittitas shadow-flicker, all turbines.pdf	2 pages

For questions please contact:

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Cell.: 760 861 6599
Email: Arne@WindEngineers.com

Project:
030326 Kittitas

Description:
For contour map
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
All turbines
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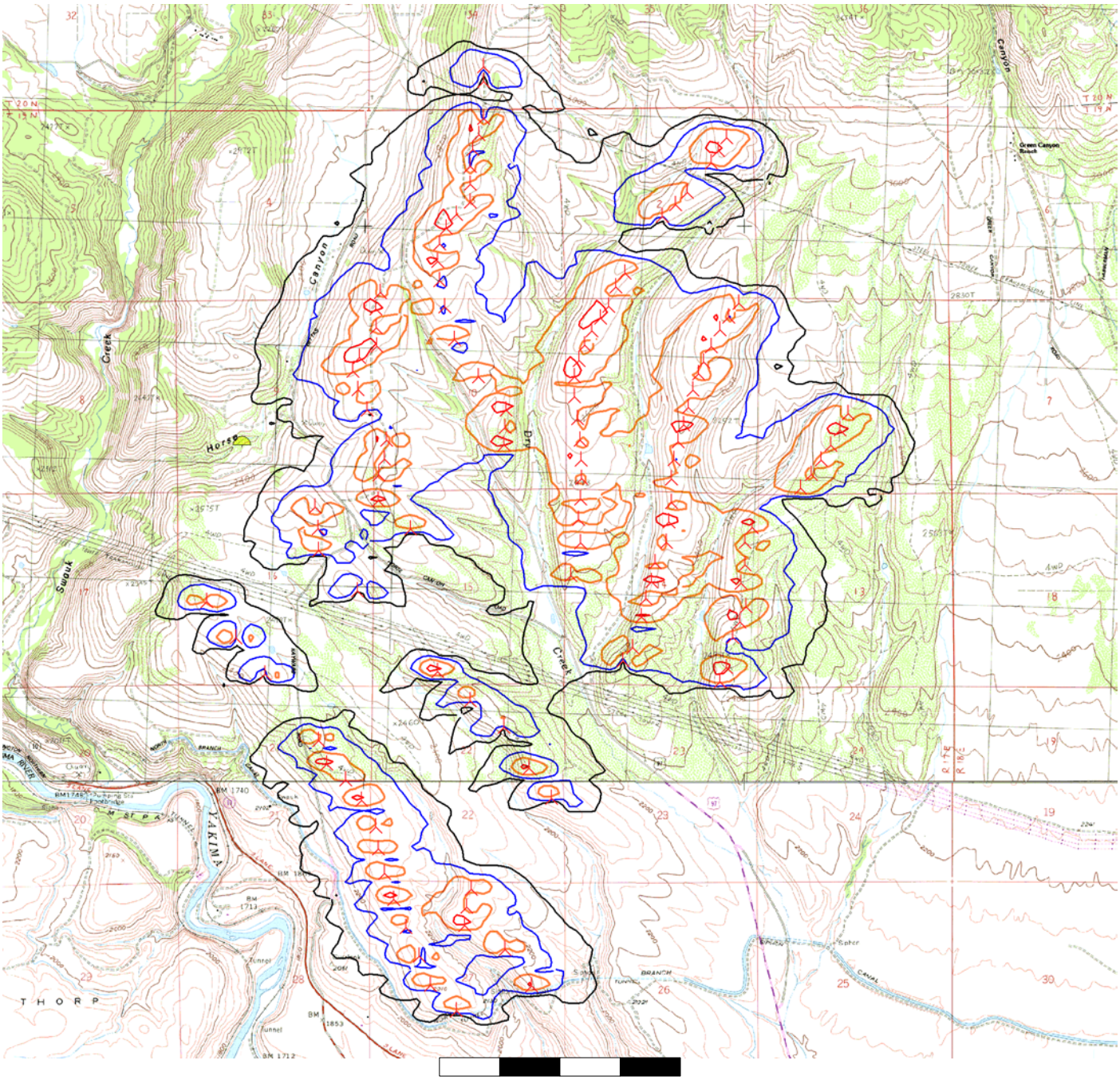
Calculation: 0304209 Shadow-Flicker, all on one **File:** 030418 ZKV 24k,mt 001.bmi



Map: 030418 ZKV 24k,mt 001 , Print scale 1:50,000, Map center UTM NAD27 Zone: 10 East: 675,245 North: 5,223,395

New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
For contour map
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
All turbines
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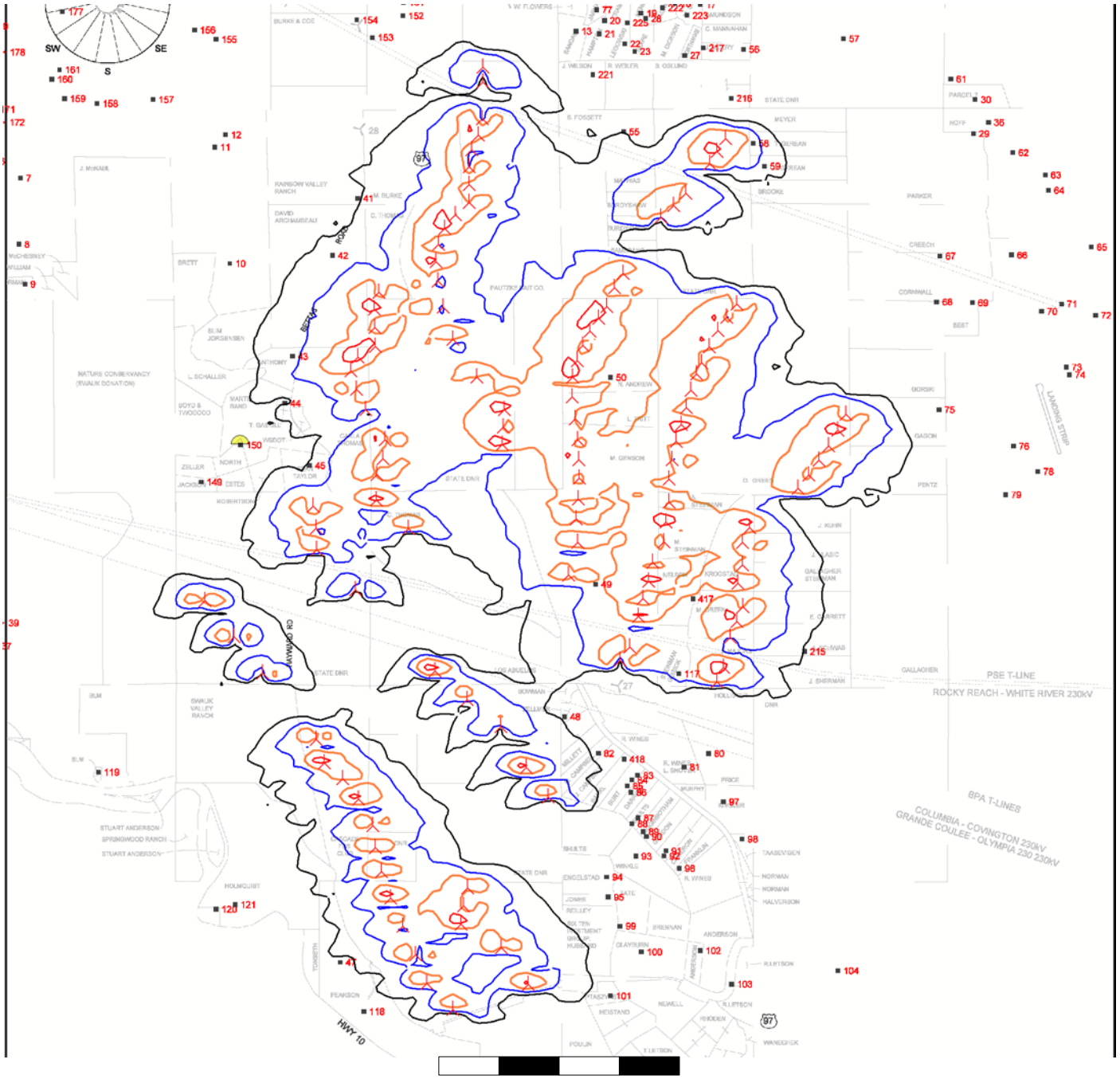

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New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptor Nelson (417N and 417W)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines I-14 through I-19 and J-08 through J-13
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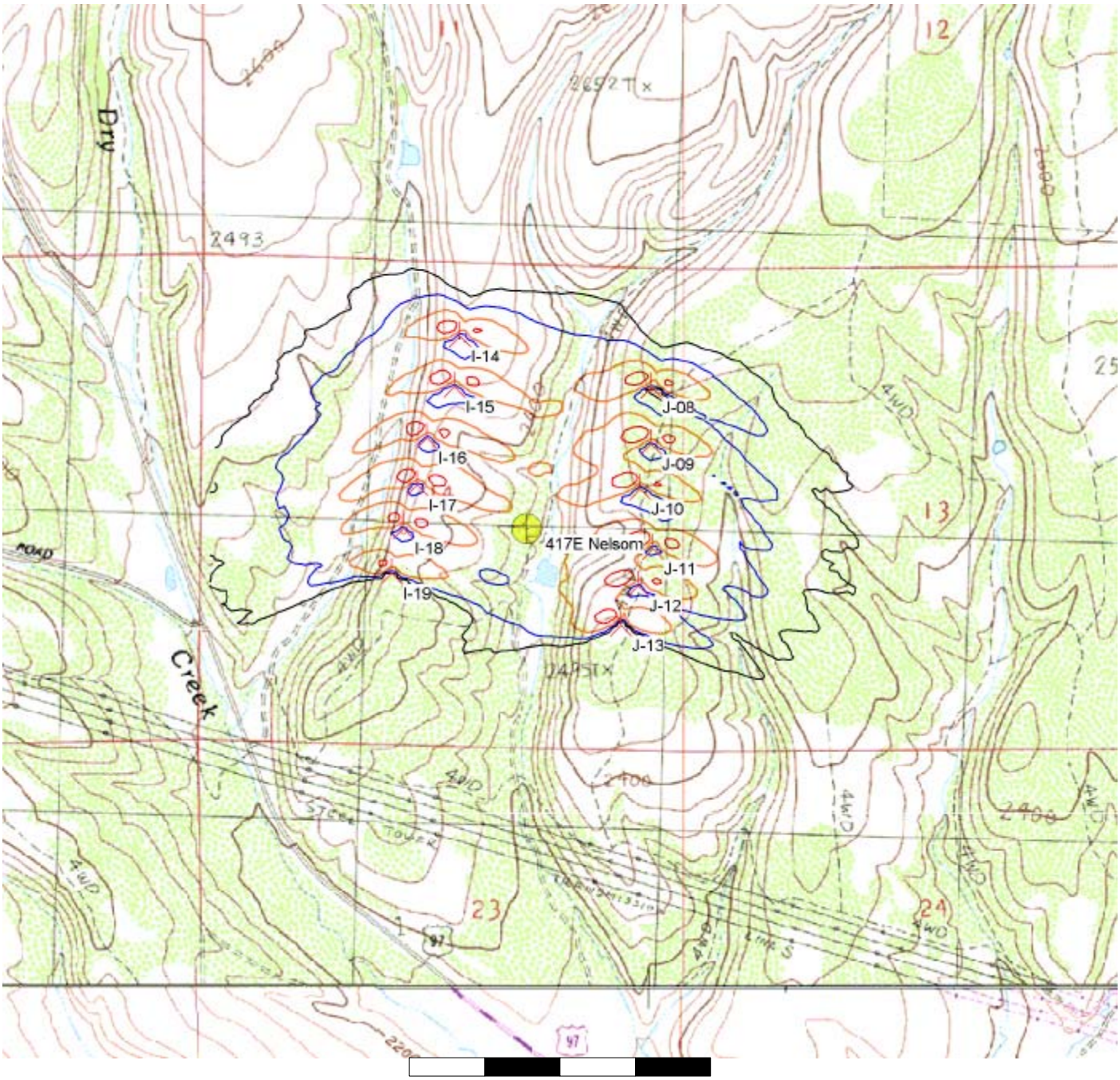

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New WTG Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptor Nelson (417N and 417W)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines I-14 through I-19 and J-08 through J-13
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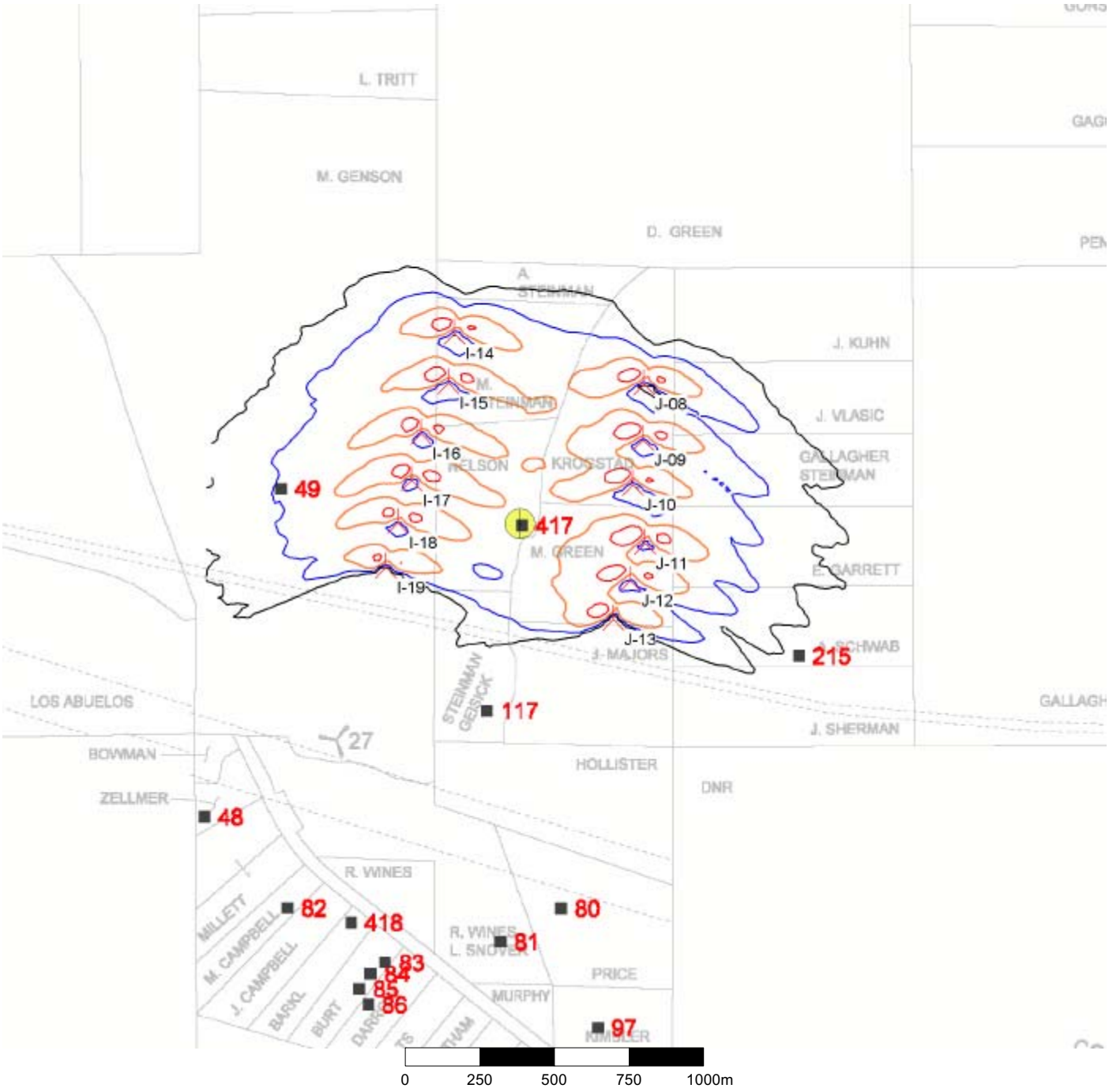

Map: z-fig101-houses2 , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 676,585 North: 5,222,935

New WTG Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptor Taylor (045S and 045E)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines D-01 and D-02, F-09 through F-12
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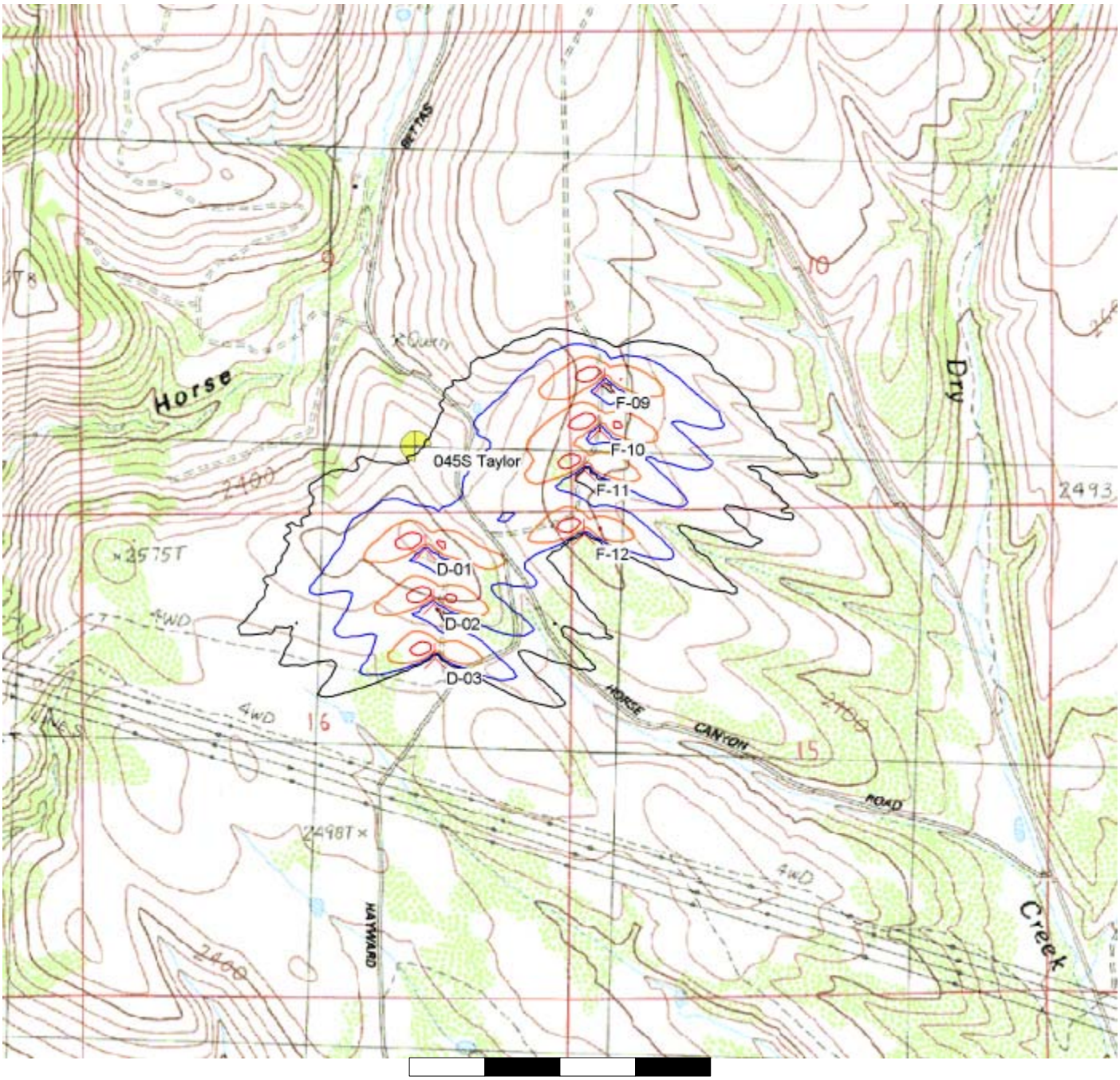

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New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptor Taylor (045S and 045E)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines D-01 and D-02, F-09 through F-12
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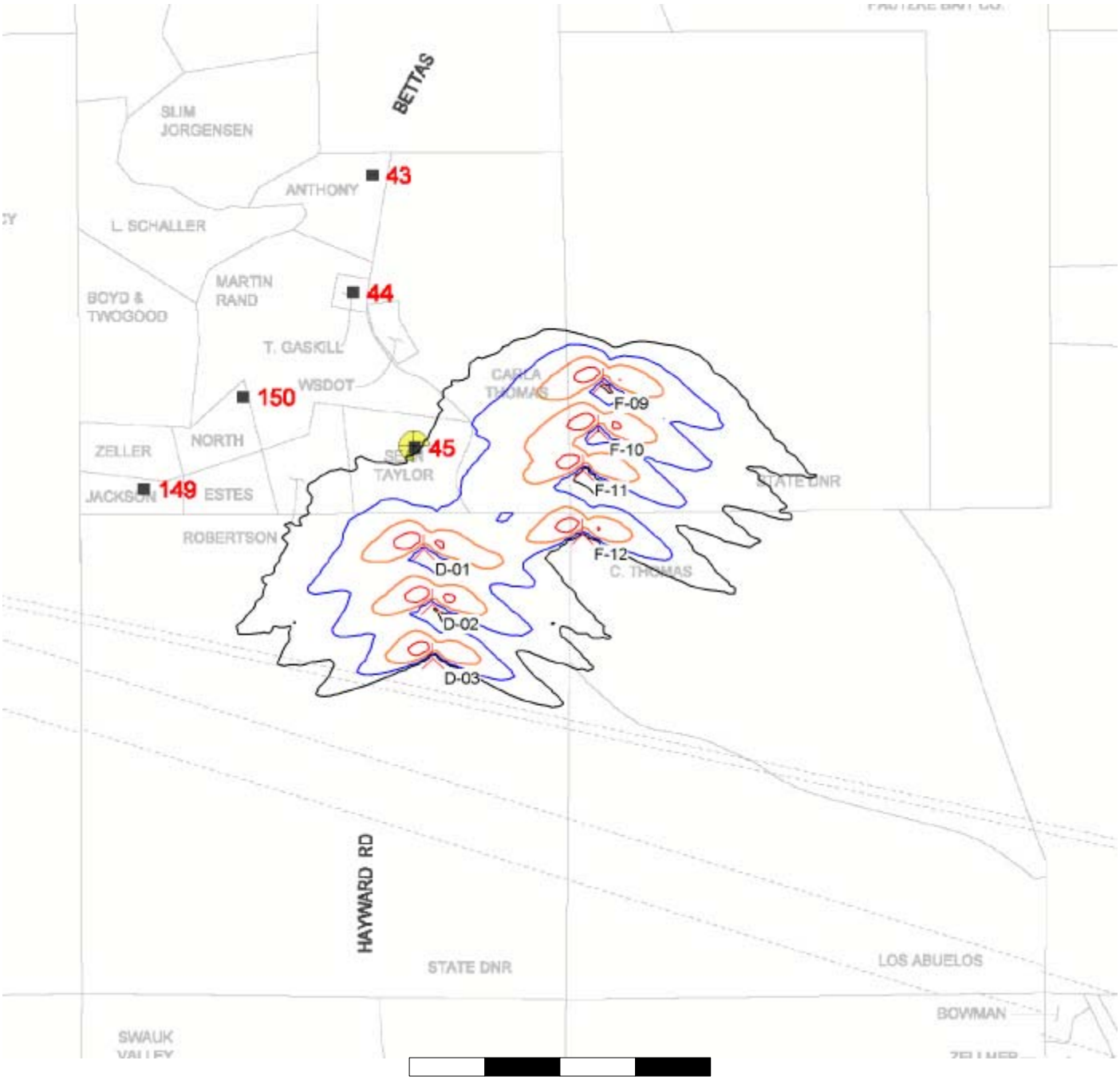
Calculation: 030419 Shadow-Flicker, D-01-02 and F-09-12, on 045S and 045E **File:** z-fig101-houses2.bmi



Map: z-fig101-houses2 , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 673,735 North: 5,223,685

New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptor Price and Schwab (080N and 215W)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines J-10 through J-15
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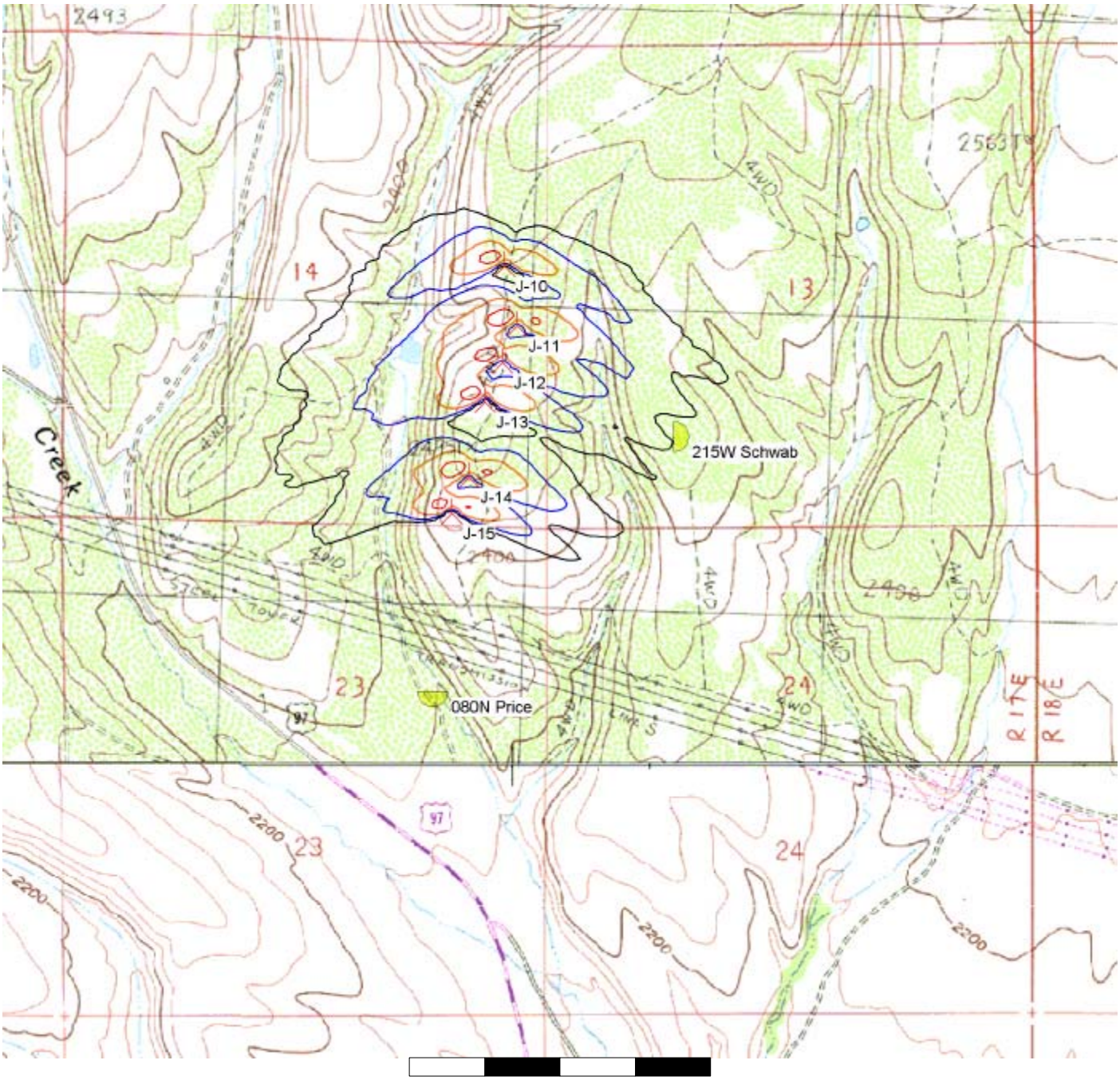

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New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptor Price and Schwab (080N and 215W)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines J-10 through J-15
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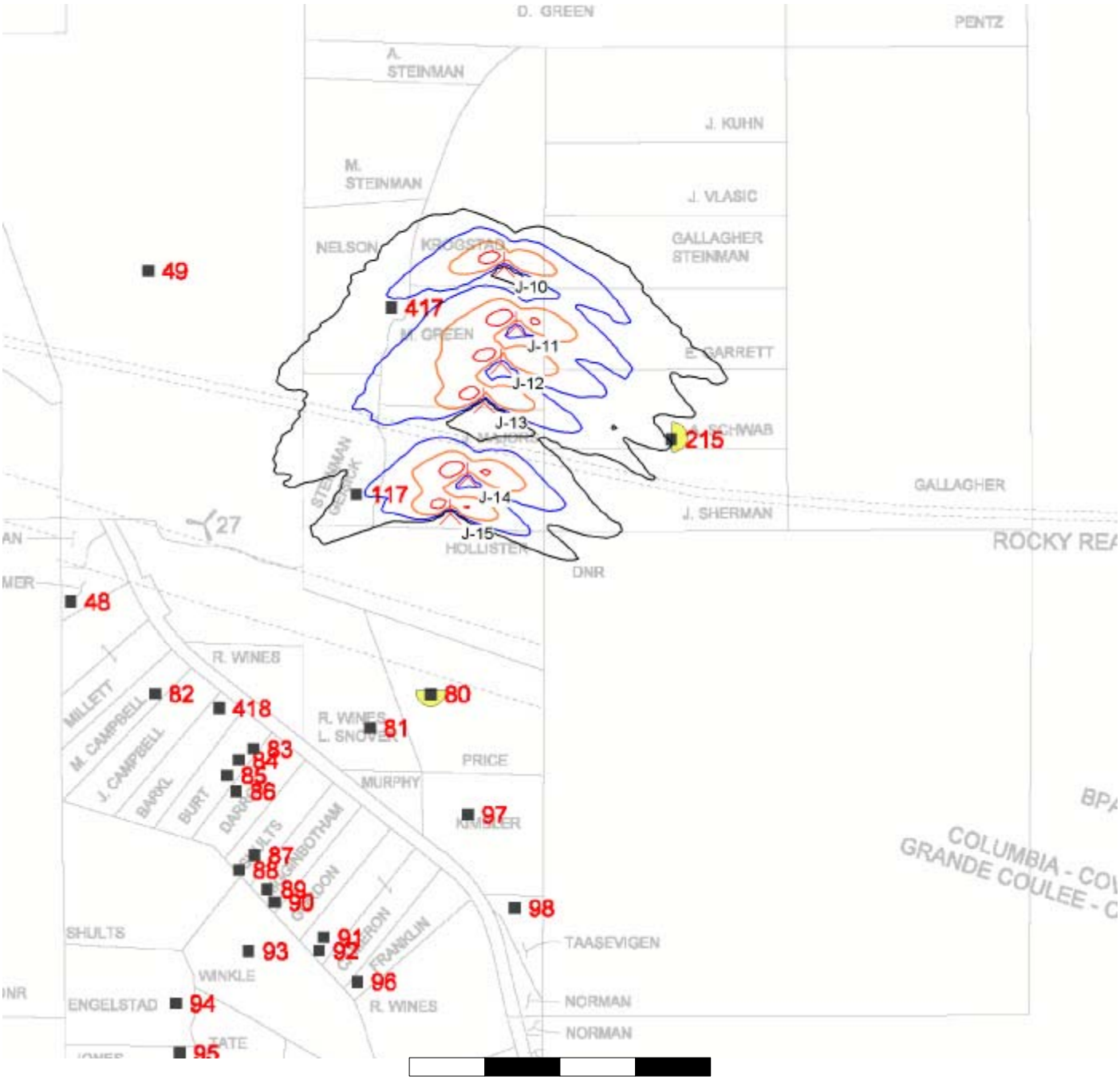

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New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptors Pearson (047E, 118E)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines B-07 through B-12
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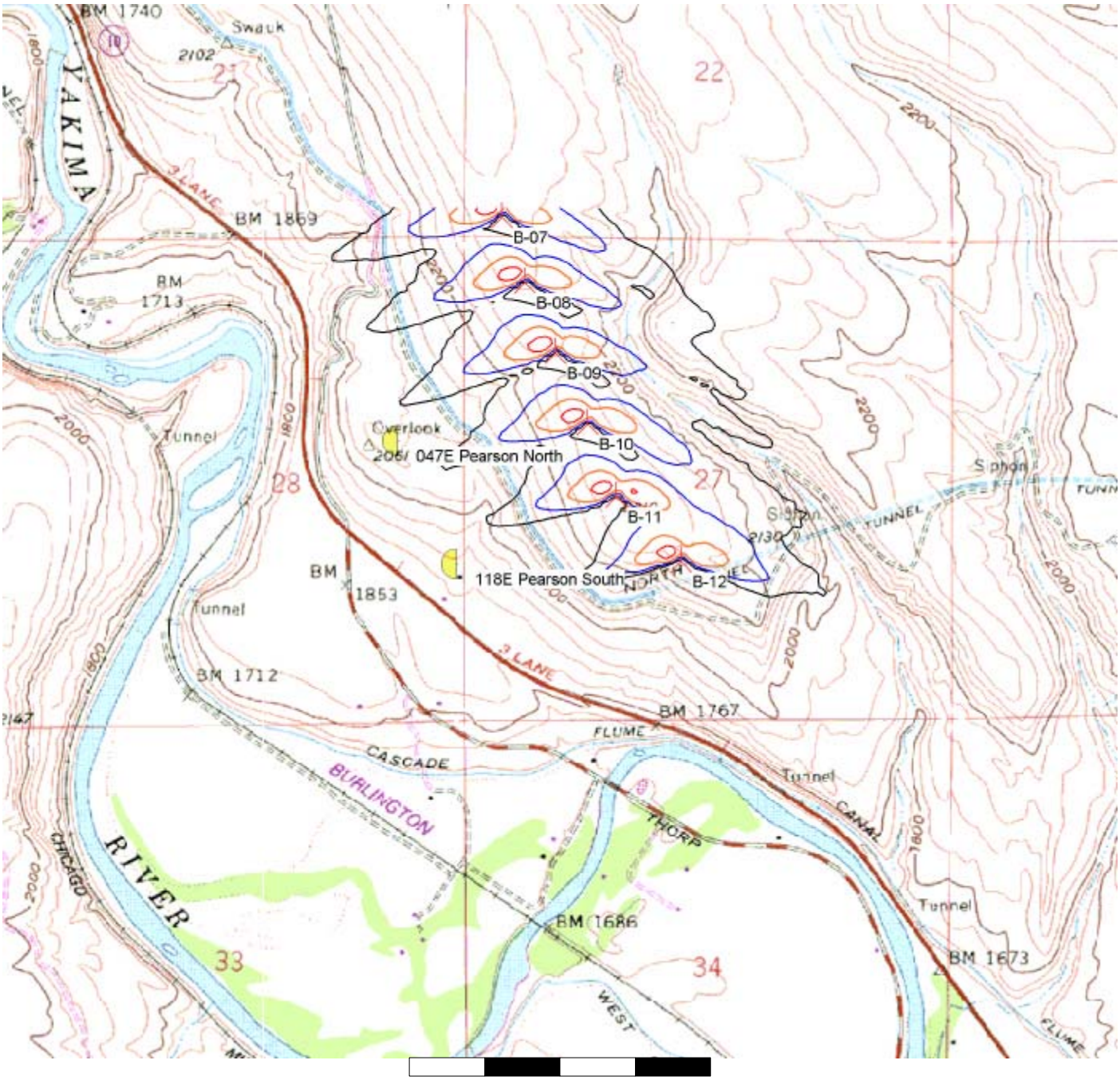
Calculation: 0304209 Shadow-Flicker, B-07-12, on 047E and 118E **File:** 030418 ZKV 24k,mt 001.bmi



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New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptors Pearson (047E, 118E)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines B-07 through B-12
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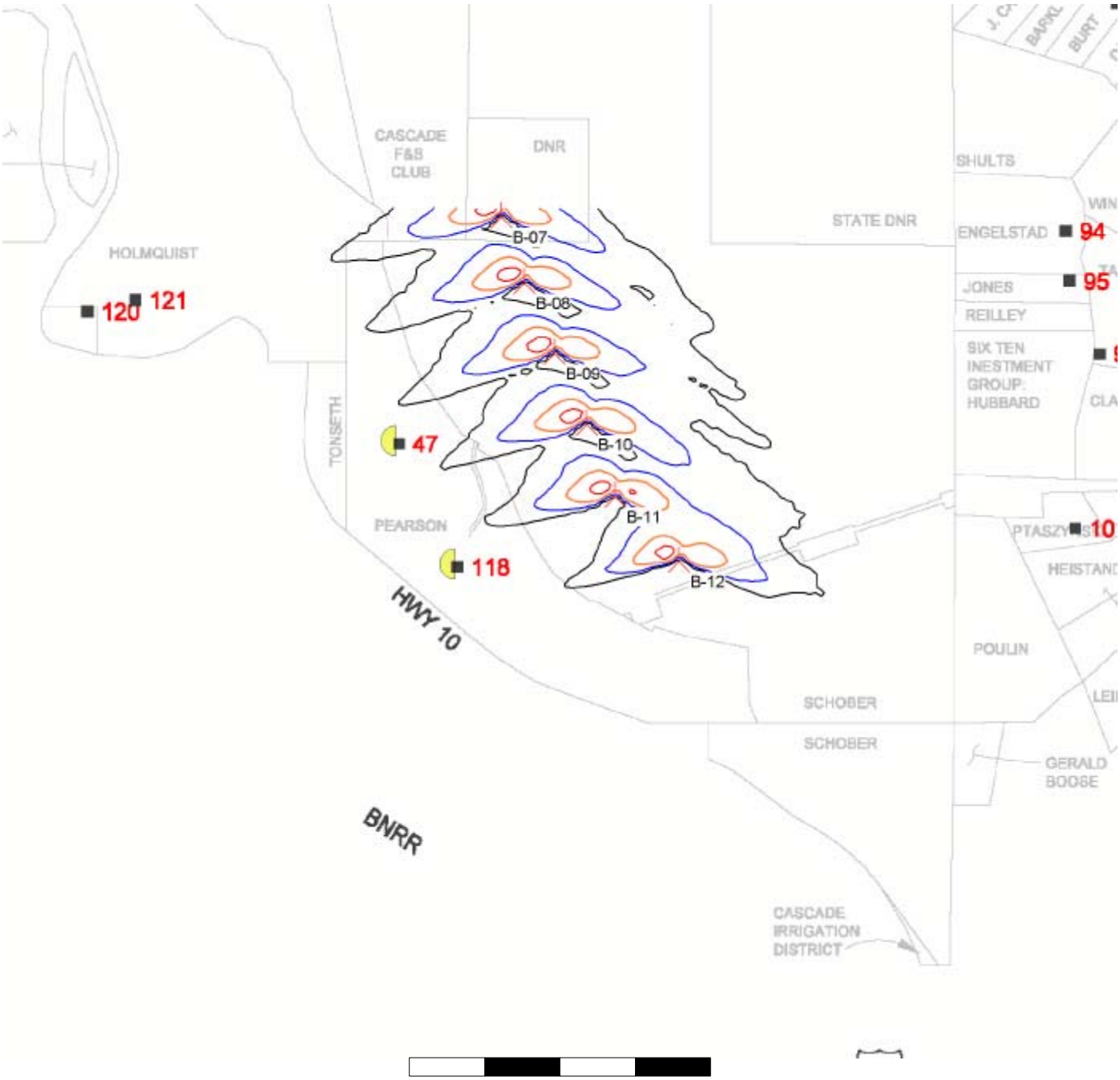

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New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptors Zellmer, Campbell, Burt and Darrow (048SW, 082SW, 084SW and 086SW)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines E-01 through E-05
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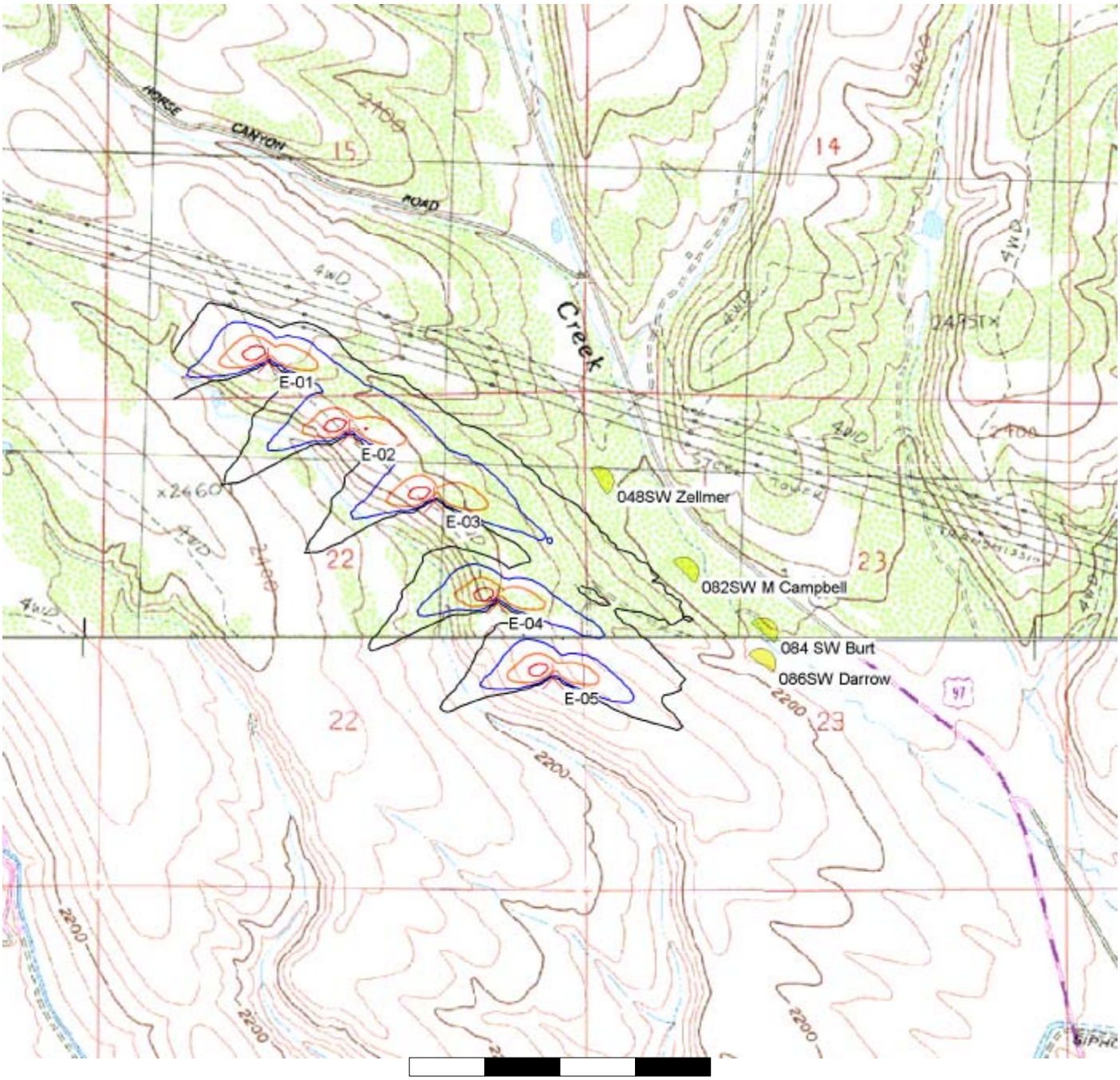
Calculation: 030419 Shadow-Flicker, E-01-05, on 048SW, 082SW, 084SW and 086SW **File:** 030418 ZKV 24k,mt 001.bmi



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New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptors Zellmer, Campbell, Burt and Darrow (048SW, 082SW, 084SW and 086SW)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines E-01 through E-05
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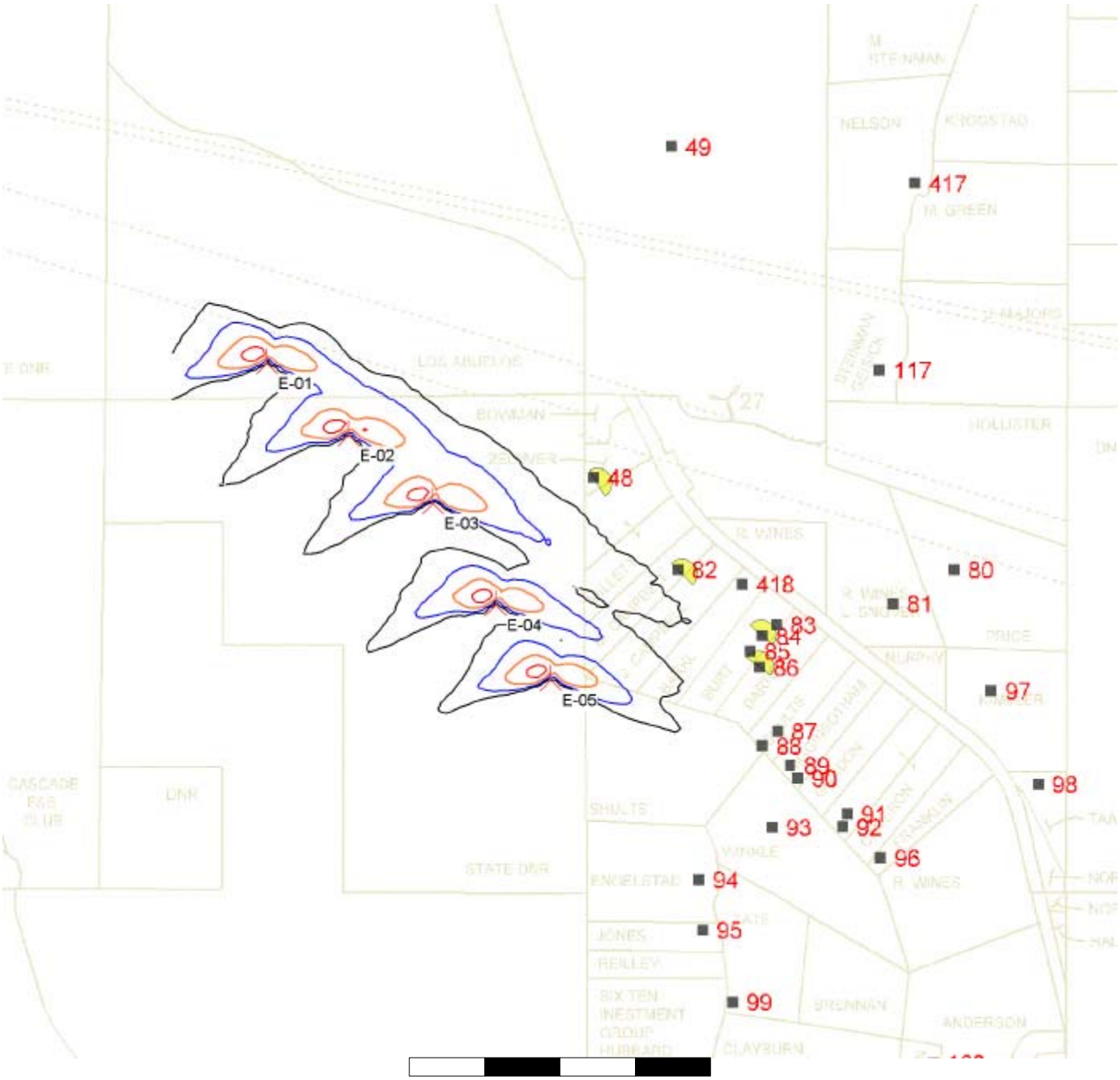
SHADOW - z-fig101-houses

Calculation: 030419 Shadow-Flicker, E-01-05, on 048SW, 082SW, 084SW and 086SW **File:** z-fig101-houses.bmi



Map: z-fig101-houses , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 675,335 North: 5,221,735

New WTG
Shadow Receptor
Isolines showing shadow in Shadow hours per year. Real value calculation.
25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptors Gaskill and Anthony (044E, 043E)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines F-01 through F-10
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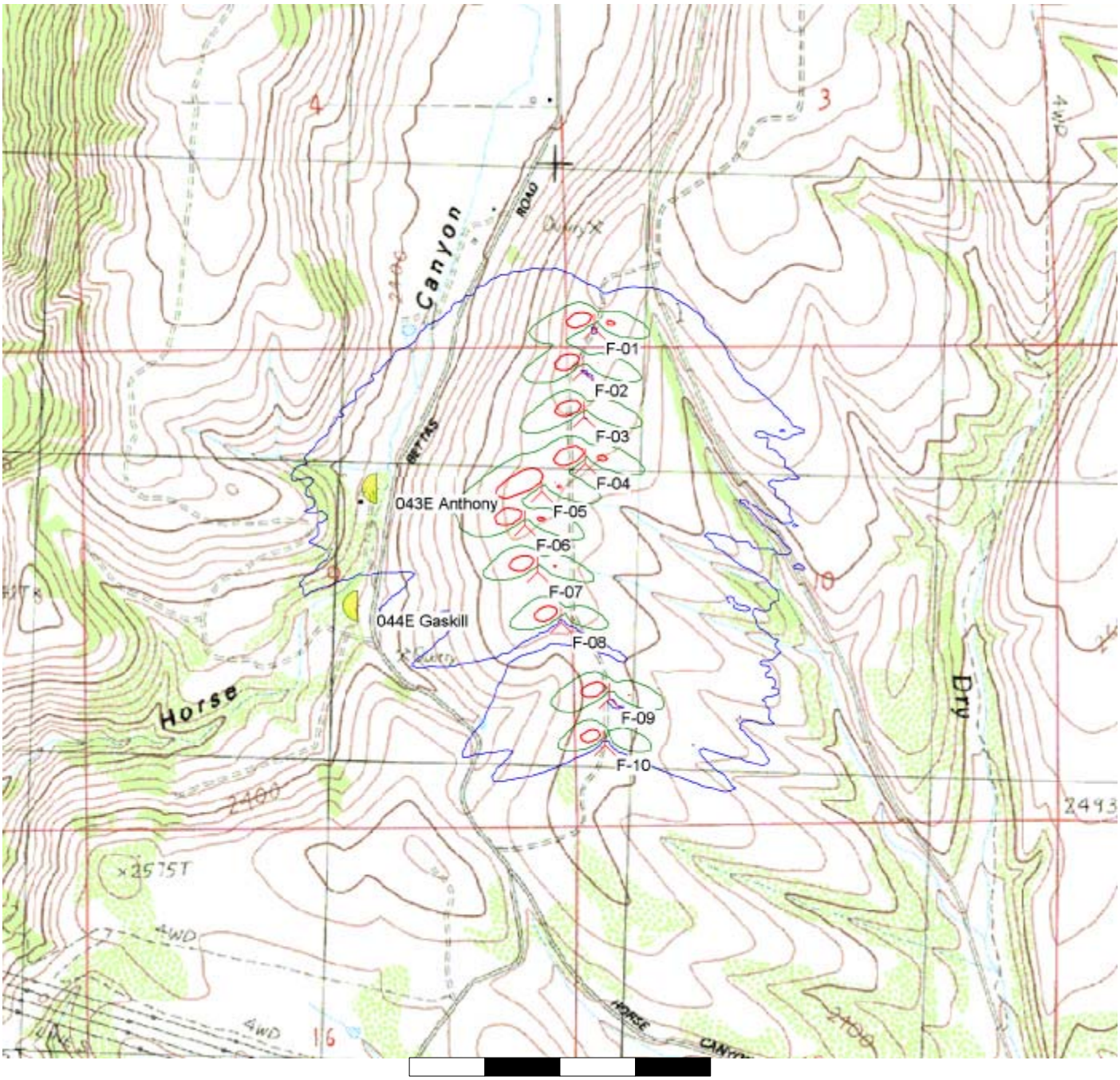

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New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 100 200

Project:
030326 Kittitas

Description:
Shadow receptors Gaskill and Anthony (044E, 043E)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines F-01 through F-10
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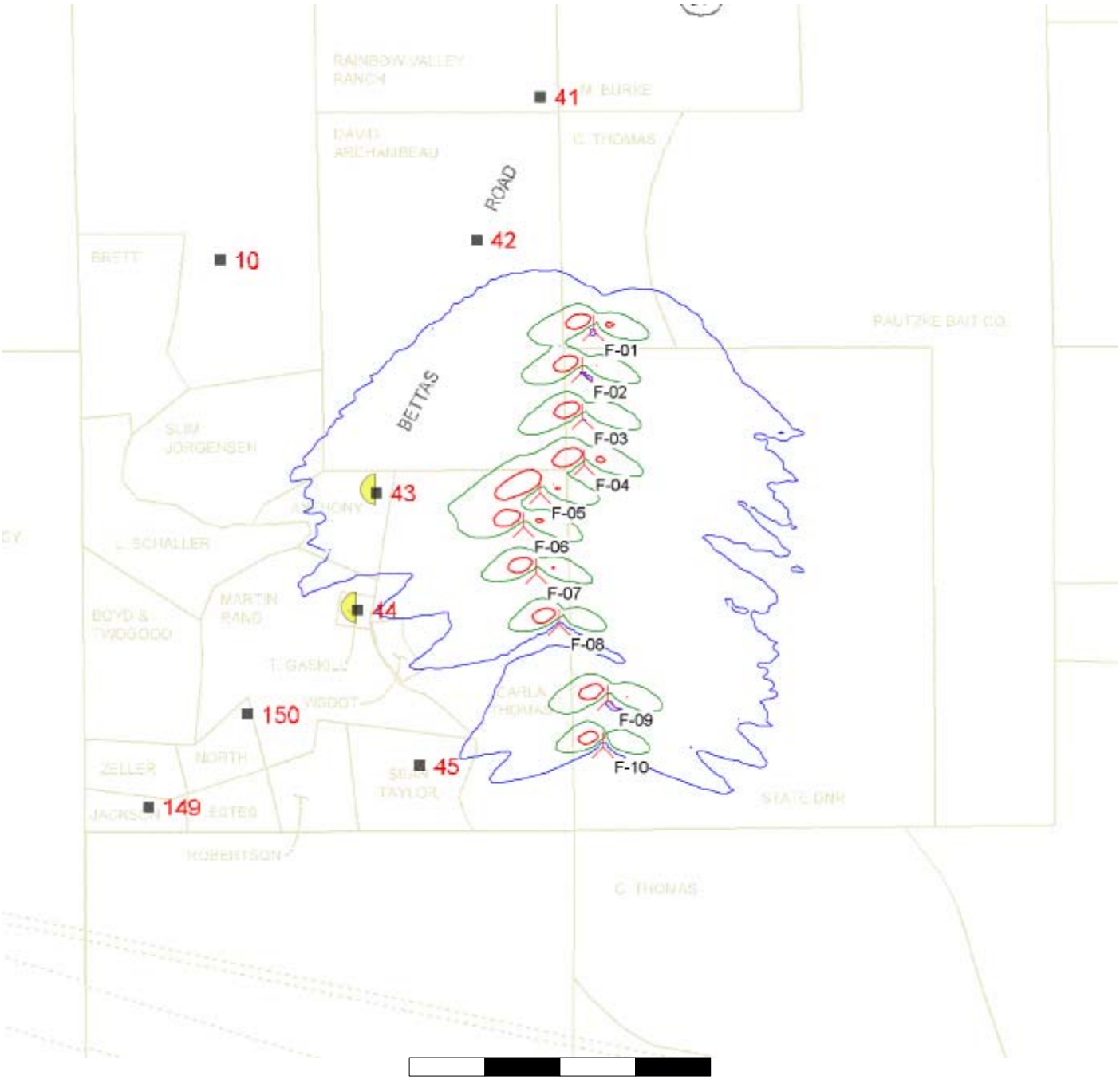
SHADOW - z-fig101-houses

Calculation: 030419 Shadow-Flicker, F-01-10, on 043E and 044E **File:** z-fig101-houses.bmi



Map: z-fig101-houses , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 673,685 North: 5,224,735

New WTG
Shadow Receptor
Isolines showing shadow in Shadow hours per year. Real value calculation.
25 100 200

Project:
030326 Kittitas

Description:
Shadow receptor T Gerean and L Gerean (058W and 059W)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines H-01 through H-04
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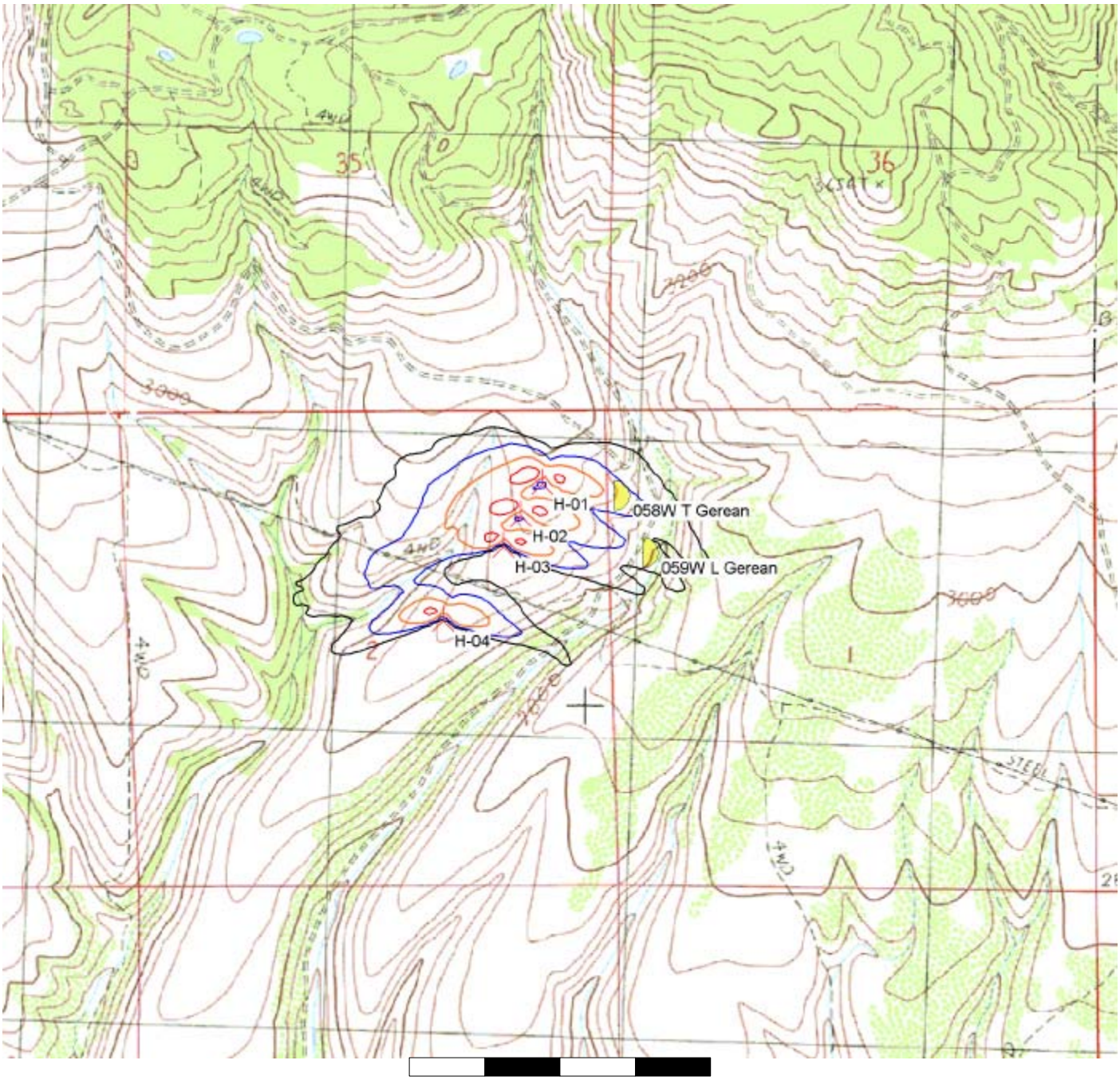
Calculation: 030418 Shadow-Flicker, H-01-04, on 058W and 059W **File:** 030418 ZKV 24k,mt 001.bmi



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Map: 030418 ZKV 24k,mt 001 , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 676,685 North: 5,226,635

New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptor T Gerean and L Gerean (058W and 059W)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines H-01 through H-04
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04/22/2003 02:41 / 8
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CA-92506 Riverside, USA

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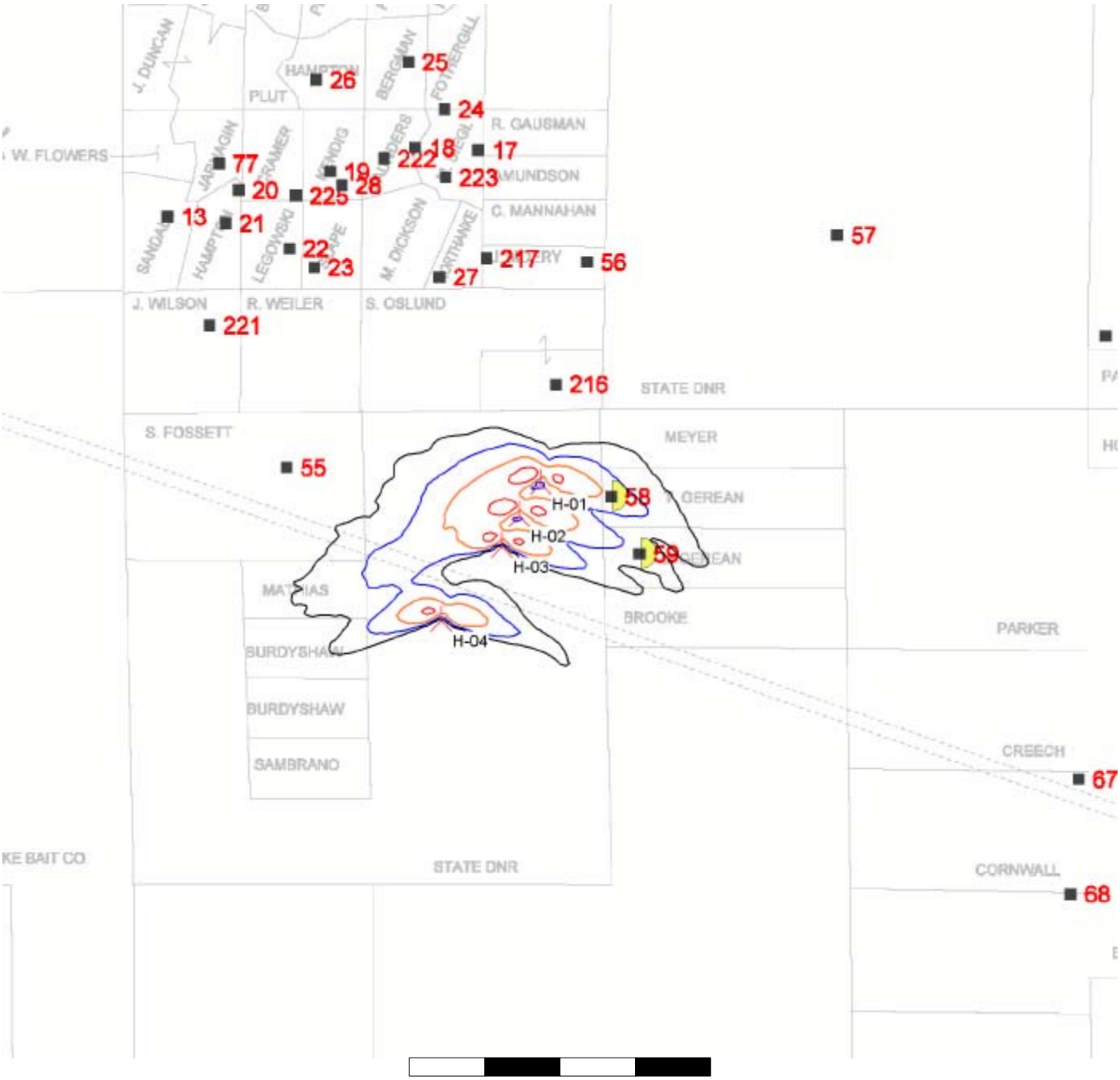
04/19/2003 08:55/2.3.0.125

SHADOW - z-fig101-houses2

Calculation: 030418 Shadow-Flicker, H-01-04, on 058W and 059W **File:** z-fig101-houses2.bmi



0 250 500 750 1000m

Map: z-fig101-houses2 , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 676,685 North: 5,226,635

New WTG Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptor Giesick (117E and 117W - east and west windows)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines I-18 through I-21 and J-12 through J-15
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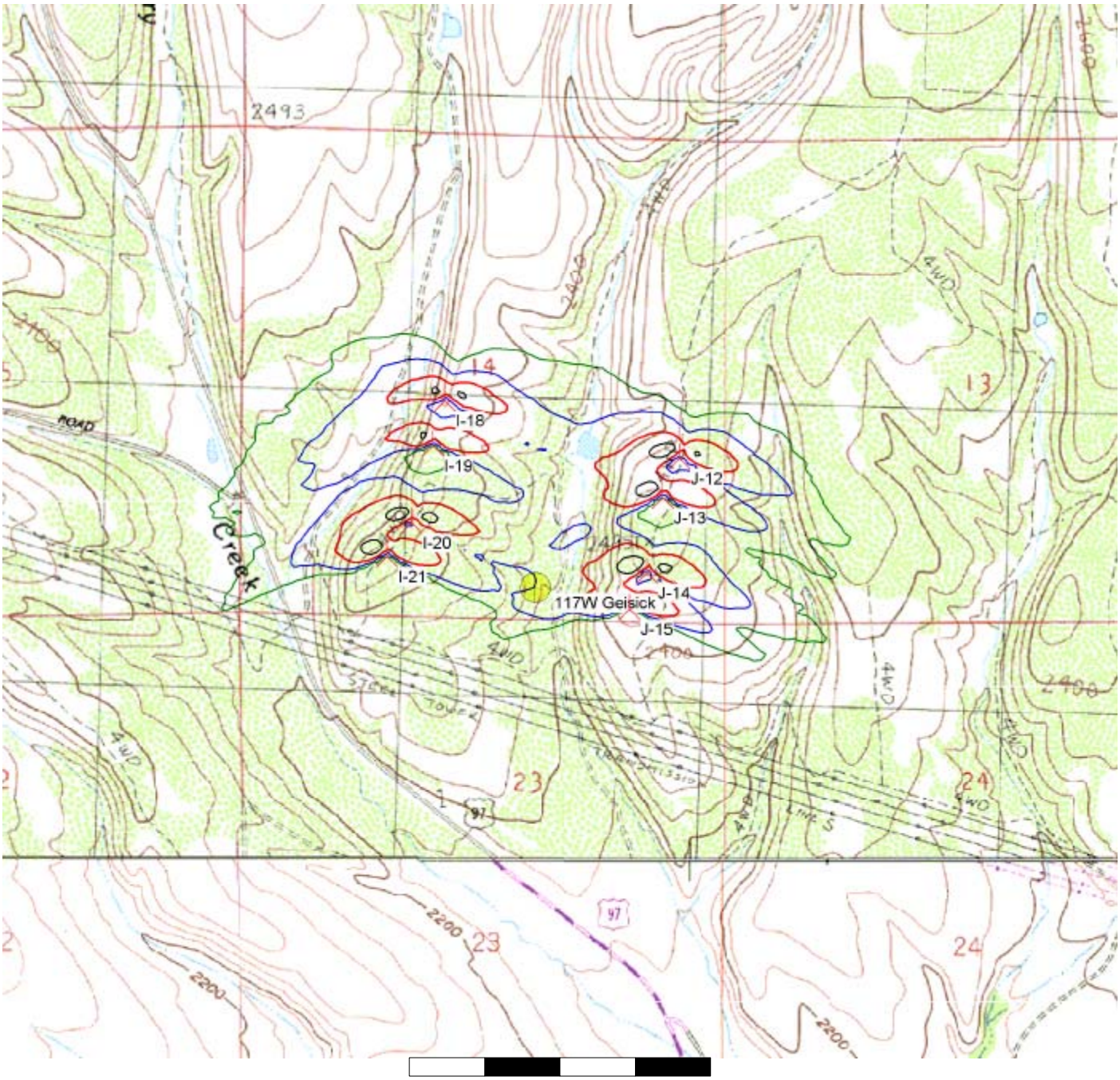
SHADOW - Bitmap map: 030418 ZKV 24k,mt 001.bmi

Calculation: 030416 Shadow-Flicker, I18-21 and J-12-15, on 117 **File:** 030418 ZKV 24k,mt 001.bmi



0 250 500 750 1000m

Map: 030418 ZKV 24k,mt 001 , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 676,460 North: 5,222,506

New WTG
Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
Shadow receptor Giesick (117E and 117W - east and west windows)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines I-18 through I-21 and J-12 through J-15
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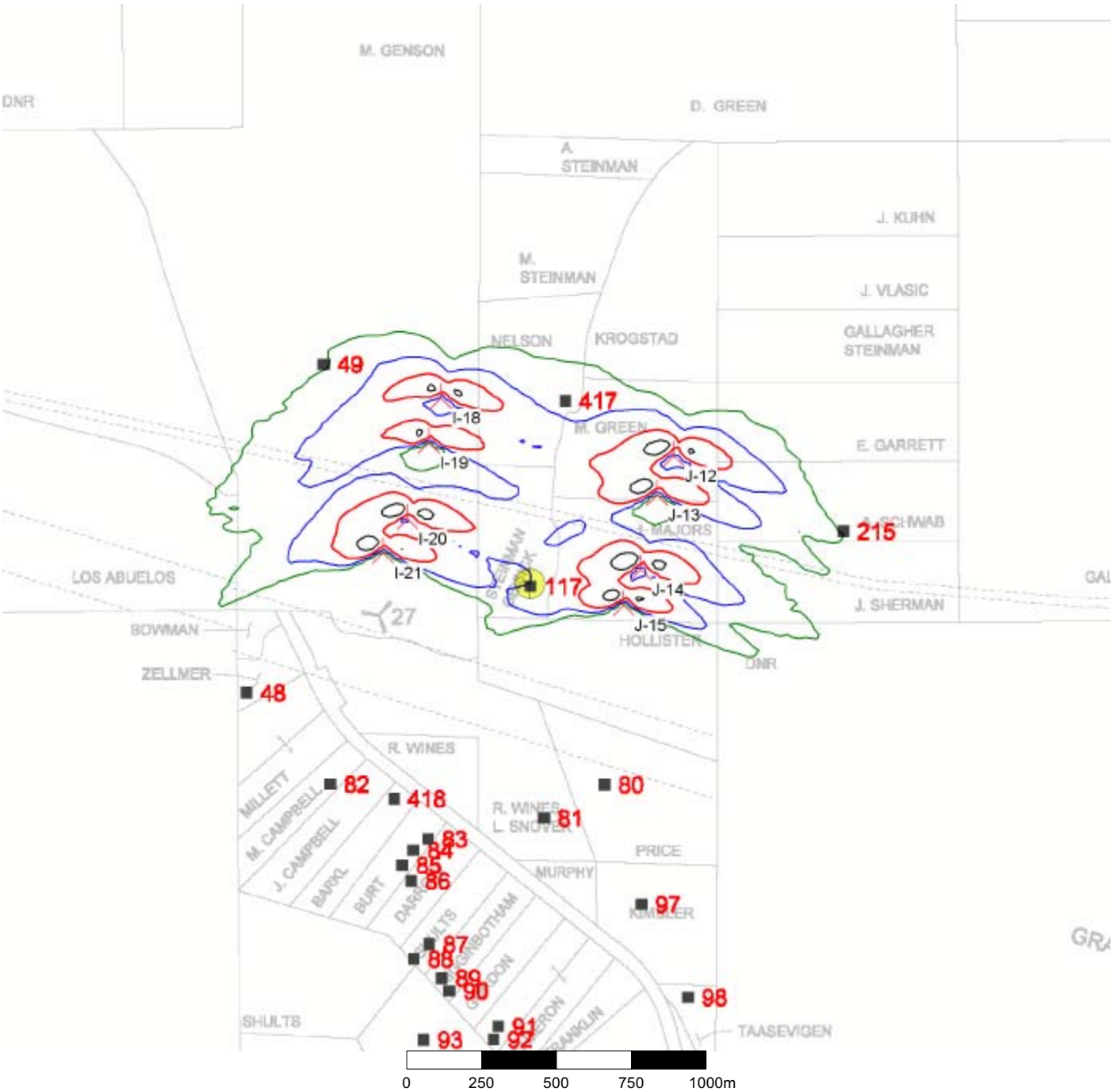
SHADOW - z-fig101-houses2

Calculation: 030416 Shadow-Flicker, I18-21 and J-12-15, on 117 **File:** z-fig101-houses2.bmi



Map: z-fig101-houses2 , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 676,460 North: 5,222,506

New WTG Shadow Receptor

Isolines showing shadow in Shadow hours per year. Real value calculation.

25 50 100 200