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Freeway Performance Measurement System (PeMS), PeMS 6.5

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Freeway Performance Measurement System (PeMS), PeMS 6.5:

Final Report for CCIT TO 16

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Executive summary

Under development and operation since 1999, PeMS now is the *de facto* repository for all Caltrans fixed-location detector data. The system is used to investigate everything from the characteristics of individual loop detectors to highly aggregated performance trends across Caltrans districts. PeMS usage has grown continuously and it now supports 3000-4000 reports per day (plots, tables, etc). It distributes data to 55 registered Value Added Resellers, 20 of which actively retrieve real-time data.

PeMS is located on the U.C. Berkeley campus. During the past few months, a copy of PeMS has been installed at Caltrans. Caltrans is currently determining the steps to transition that instance of PeMS to active service. Once it goes live, Caltrans PeMS will be a 24×7 production facility. UCB PeMS will then become a platform for developing new algorithms and features.

The PeMS 6.5 effort completed six tasks.

1. Connecting D6 to PeMS

Caltrans District 6 has 14 VDS stations comprised of 42 lane detectors along State Route 41 through downtown Fresno. They started sending real-time data to PeMS in August of 2005. D6 is now fully integrated into PeMS.

2. Separate out D5 detectors into separate district

Caltrans District 5 has 10 VDS stations in the northern part of the district deployed along State Routes 1, 17 and 25. Since these stations are so close to District 4, D4 has been collecting data from these stations in real-time. This data has been flowing to PeMS through the D4 feed since 2001. Due to the limitations of the original design of PeMS it was not possible at that time to separate these detectors out of the D4 feed and associate them with District 5. This limitation was changed with this task and now D5 is its own district in PeMS.

3. "Joe Avis" reports – exporting to the TMG format

Joe Avis is the manager of the Traffic Census Group in Caltrans. For this task we built into PeMS the ability to export data to a format that Joe Avis and his team can use to import into TSN. More formally, this format is specified in the FHWA Traffic Monitoring Guide and we refer to it as the TMG format.

4. Additional PeMS user interface requests

As engineers in Caltrans have become accustomed to using PeMS, they have started to request additional types of reports that more closely match their job functions. This task included producing a few reports that were requested by individuals inside of Caltrans.

5. PeMS data server

PeMS now provides a mechanism for downloading bulk data. We've set up an automatic mechanism to export the data from PeMS to an FTP site so that researchers and consultants can download the data in flat-file format. The expectation is that this will greatly extend the use of the data.

6. Web-based configuration management

We have transitioned all of the detector configuration management tools to web pages within PeMS. The district personnel in charge of providing configurations to PeMS can now upload their configurations to PeMS through a web page, see the resulting configuration report which checks all of the configuration information for consistency, and then activate the configuration inside of PeMS. All of this can now be done without interaction with PeMS system administrators.

Introduction

PeMS 6.5 is the latest of seven task orders devoted to research, development, and maintenance of the PeMS system. While most PeMS research grants coincide with fiscal and academic years (July-June), this project started mid-year in response to a number of feature and maintenance requests (i.e. it was too late for PeMS 6 and too soon for PeMS 7).

PeMS collects, processes, stores, and makes available online data from nine Caltrans districts (D3-8, 10-12). The data are obtained from 23,871 loops[1], grouped into 9,306 vehicle detector stations (VDS). These loops cover 3,495 out of 30,572 directional-miles of interstate and state highways in California.

We now describe the accomplishments under the six tasks that constitute the PeMS 6.5 project.

Task 1 Connect District 6 to PeMS

Caltrans District 6 is located in the middle of the State. They have 14 VDS stations along State Route 41 running through downtown Fresno. District 6 collects data from the field in real-time. This is collected in the district to a standard Front End Processor (FEP) and subsequently forwarded on to an ATMS system. In this project we tapped into the real-time data distribution mechanism and started collecting the data in real-time.

[1] Some of these 'loops' are microwave radar detectors that act like loops.

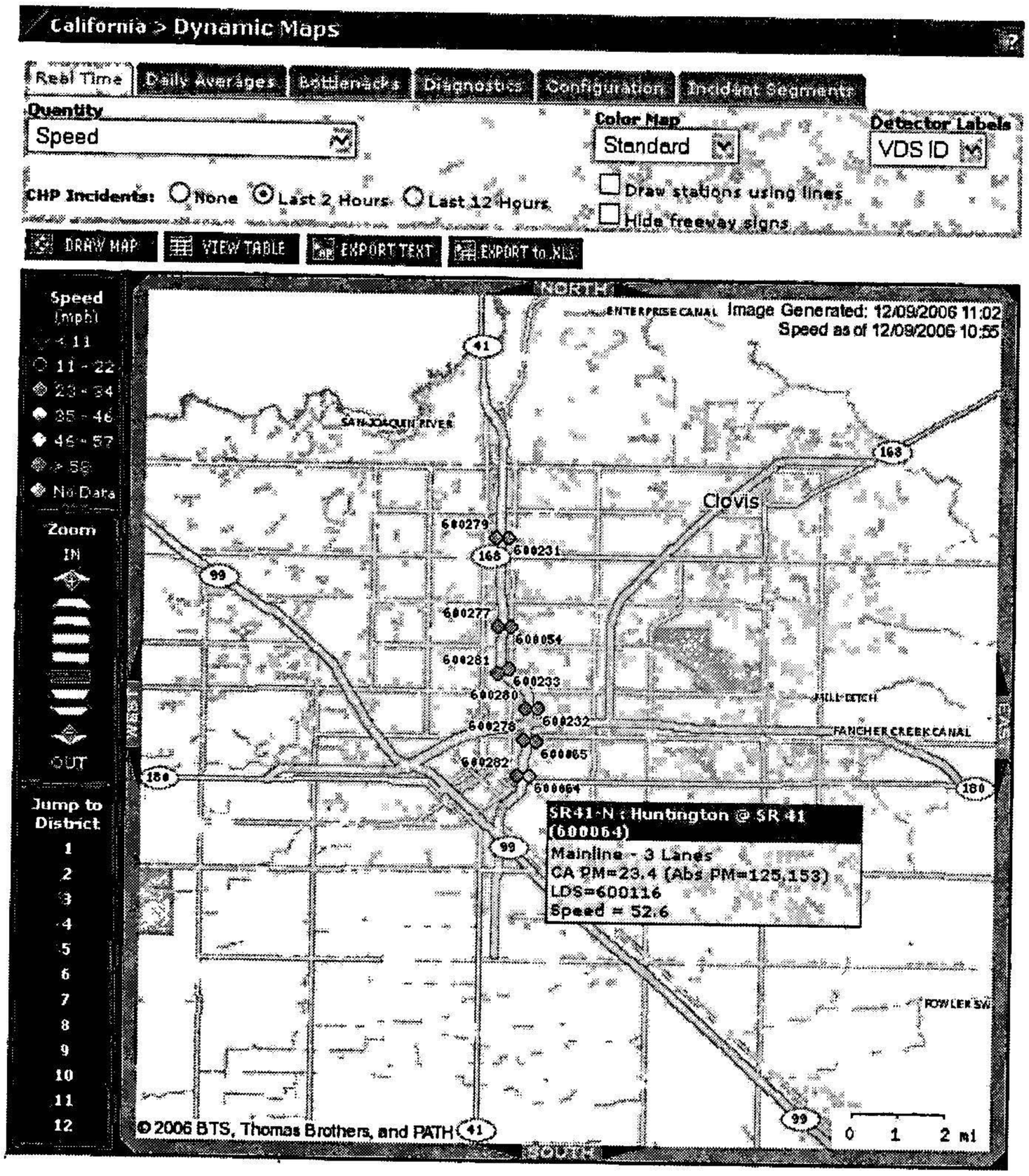


Figure 1. Standard PeMS map interface showing Caltrans District 6 with detectors along SR-41 in downtown Fresno.

To accomplish this integration we performed the following steps:

1) Configure a new data collector. Each data feed which is sent to PeMS is "captured" by a process running on a PeMS machine that we call a *data collector*. This process is in charge of translating the data from the district format to the PeMS format and then inserting it into the PeMS database.

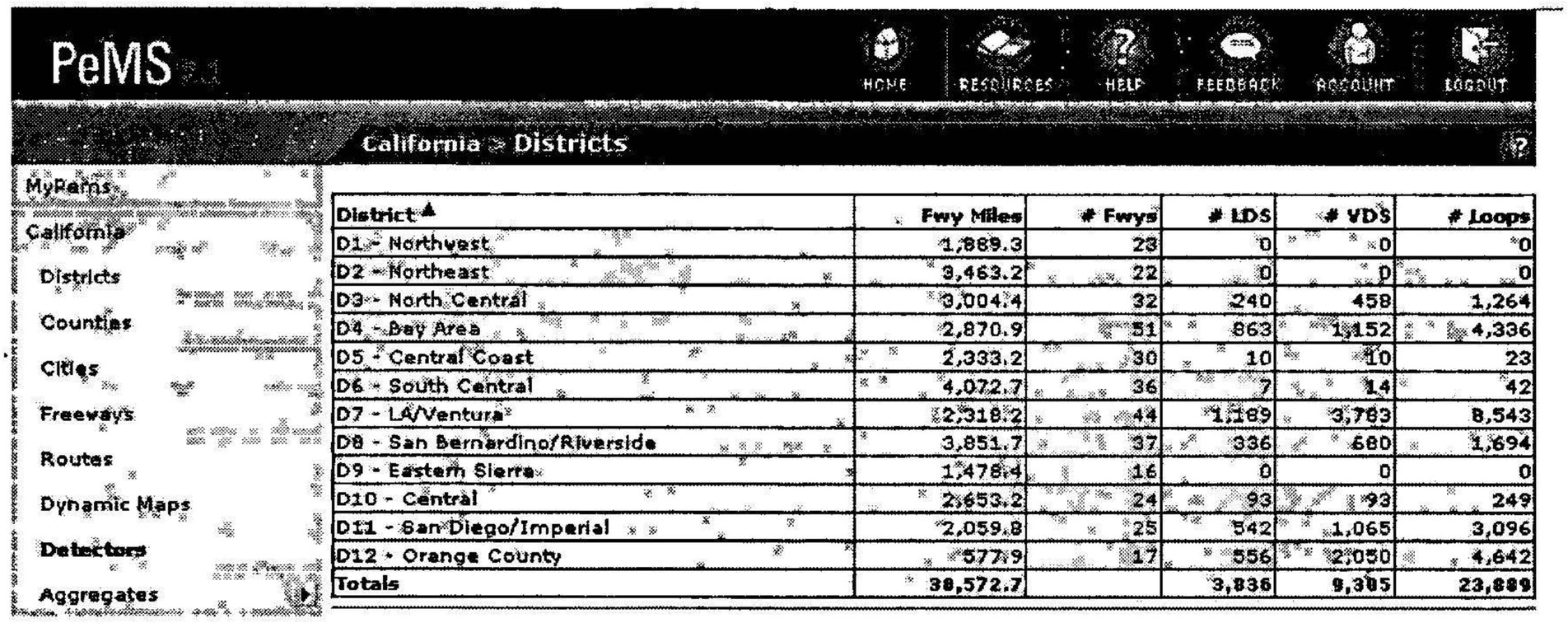
2) Incorporate the detector configuration into PeMS. Since D6 has an ATMS system we simply exported the database tables and pushed them through the configuration conversion tools that we already had for the other ATMS-based districts. We then imported this into PeMS.

3) Create the appropriate database objects to store the data. This involved setting aside tables and database structures to store the data.

4) Implement the real-time processing for this district. In PeMS each district is processed separately. This allows for the processing of a district to be placed on hold if the data feed stalls for some reason. In this task we configured the machines to start running the data processing for this district.

5) Bootstrap the district in order to compute the appropriate parameters. PeMS performs a large number of computations on the detector data. Many of these computations rely on historical data in order to compute parameters. Normally this isn't a problem because there is a lot of historical data. But when a district is just starting out, there is no data and we need to "bootstrap" this district.

All of these tasks were completed and District 6 is now a fully functional part of PeMS.



District	Fwy Miles	# Fwys	# LDS	# VDS	# Loops
D1 - Northwest	1,889.3	28	0	0	0
D2 - Northeast	3,463.2	22	0	0	0
D3 - North Central	3,004.4	32	240	458	1,264
D4 - Bay Area	2,870.9	51	863	1,152	4,336
D5 - Central Coast	2,333.2	30	10	10	23
D6 - South Central	4,072.7	36	7	14	42
D7 - LA/Ventura	2,318.2	44	1,189	3,783	8,543
D8 - San Bernardino/Riverside	3,851.7	37	336	680	1,694
D9 - Eastern Sierra	1,478.4	16	0	0	0
D10 - Central	2,653.2	24	93	93	249
D11 - San Diego/Imperial	2,059.8	25	542	1,065	3,096
D12 - Orange County	577.9	17	556	2,050	4,642
Totals	38,572.7		3,836	9,305	23,889

Figure 2. District listing page in PeMS showing District 6.

Task 2 Separate out D5 Detectors to a Separate District

In this task we separated the detectors that were coming in on the D4 real-time feed into their own district. PeMS was designed with the assumption that there is a one-to-one correspondence between a data feed and a District. This assumption has been built into many different parts of the system, including the data collection processes, the configuration management processes, and the data grinding processes. In this situation the data feed which is coming from D4 actually contains detectors which are physically located in D5. This caused a number of different problems with the PeMS system due to this original design assumption. As a result, these detectors were not displayed on the PeMS user interface.

In this task we did the work to pull the D5 detectors out of the D4 data feed and place them in their own District within PeMS.

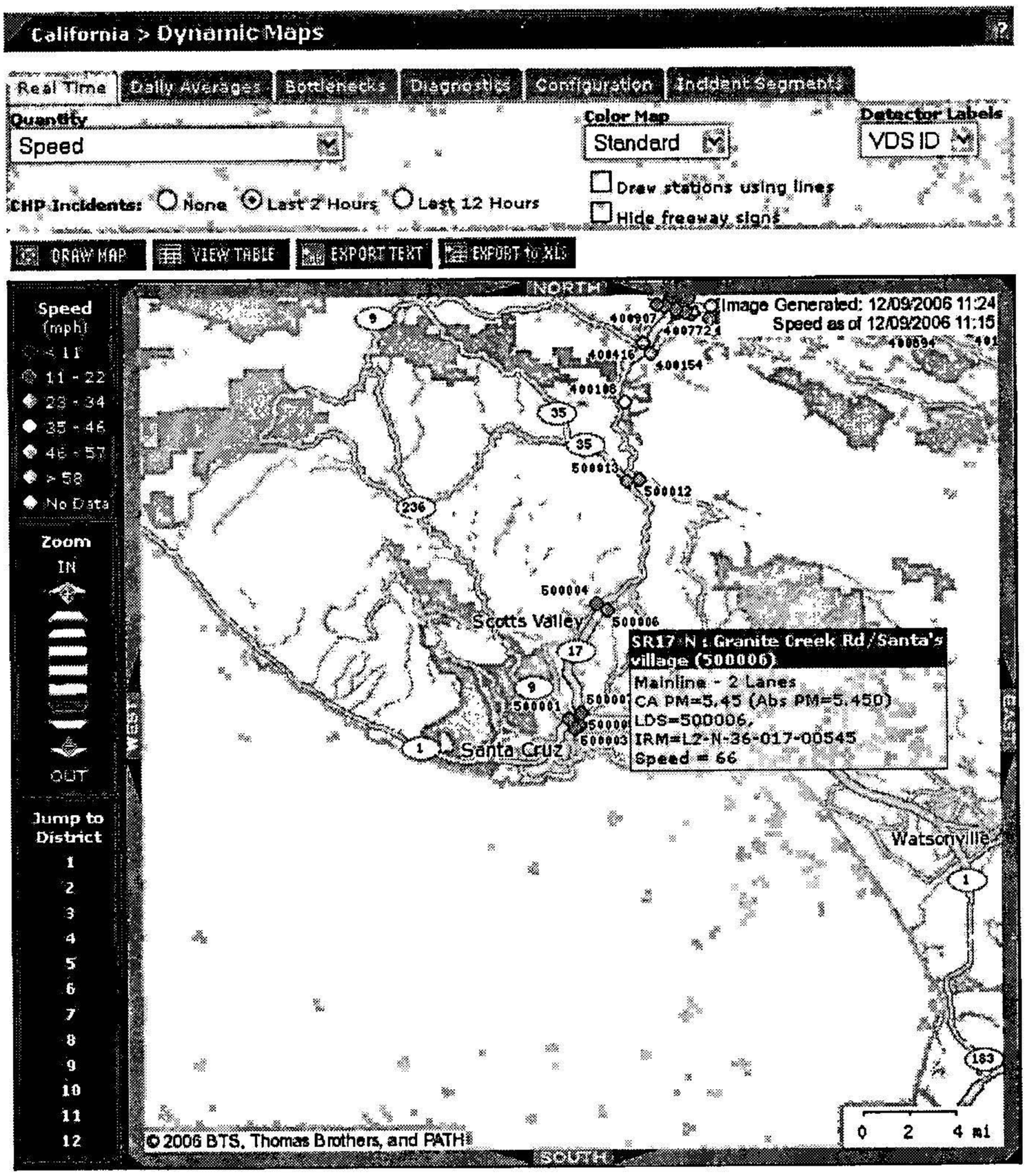


Figure 3. Real-time map in PeMS showing District 5 detectors.

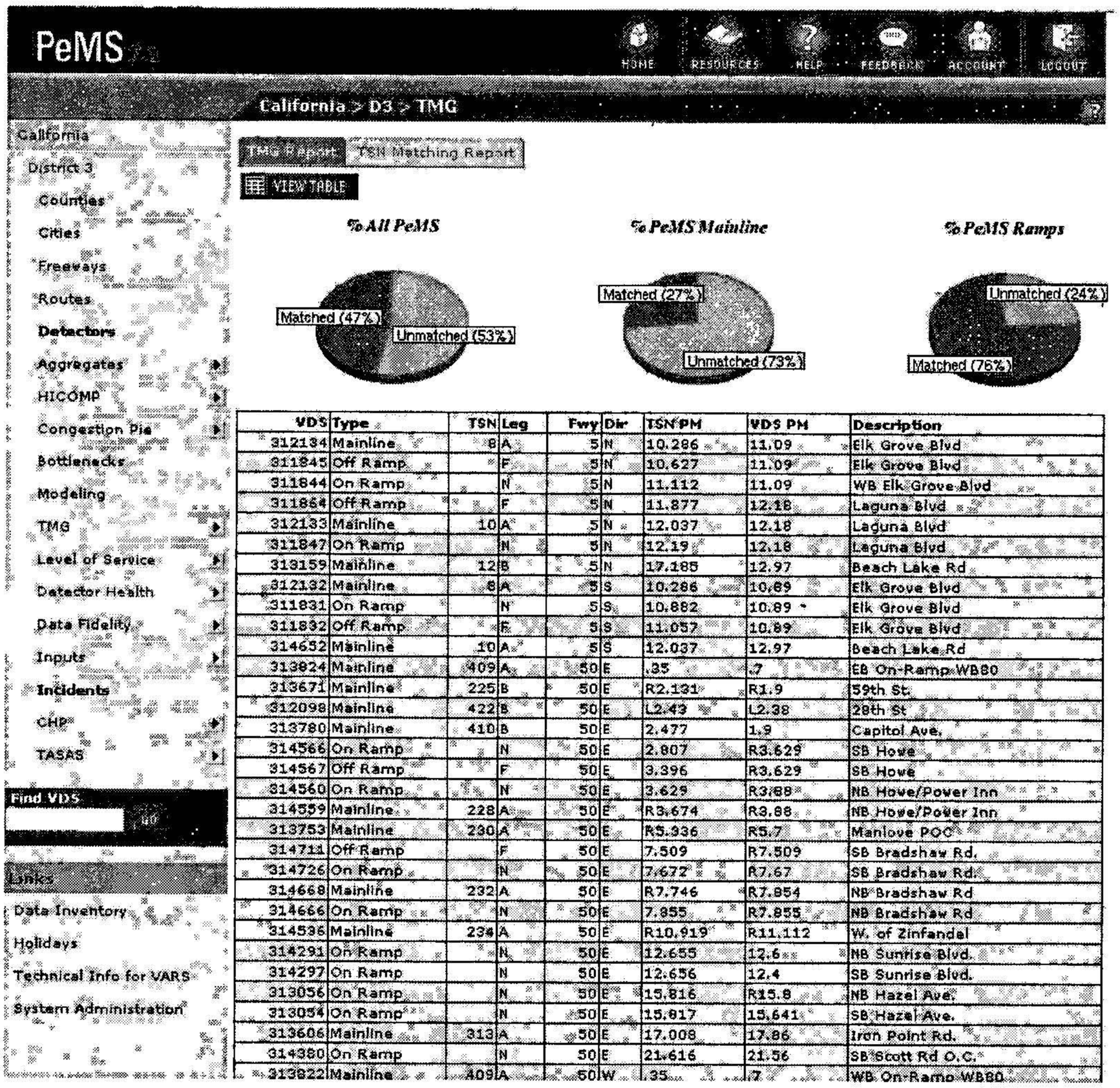
This required that we perform the same incorporation steps as a normal district, like District 6, but we also needed to modify the PeMS data collection and data configuration management scripts. These steps were done and District 5 is now treated in PeMS as its own district. Figure 3 is now the default real-time map for Caltrans District 5.

Task 3 Joe Avis Report – Exporting to the TMG Format

The Traffic Census Group at Caltrans is in charge of determining flows on the State Highway System. This is done through a separate set of sensors on the roads, or through the same sensors but through a different data collection mechanism. Counts are collected from these sensors periodically by the local district. The district is in charge of verifying that the counts are correct and that they represent typical days. These counts are then formatted to fit the FHWA Traffic Monitoring Guide format (the "TMG Format") and sent to Caltrans Headquarters to be stored in TSN.

In this task we enhanced PeMS so that it can generate the TMG Format for any detector feeding data to PeMS. This will allow Caltrans engineers to export the current data being collected by the TMC sensors in the PeMS system to a format that can be fed directly into TSN. These can then be compared with the associated, or closest, Census Station.

The first step of this task was to write a program that matched the Census Station IDs to the VDS IDs stored in PeMS. While some of the stations might be the same physical devices in the road, and others might be close by, the relationship between the Census Station ID and the "matching" VDS IDs are unknown. In other words, nobody knew which Census Station was closest to which PeMS VDS station. The program that we wrote applied some simple matching rules in order to associate the two sets. We store this matching in PeMS and the results are presented to users via a series of pages.



VDS	Type	TSN	Leg	Fwy	Dir	TSN PM	VDS PM	Description
312134	Mainline	8	A	5	N	10.286	11.09	Elk Grove Blvd
311845	Off Ramp		F	5	N	10.627	11.09	Elk Grove Blvd
311844	On Ramp		N	5	N	11.112	11.09	WB Elk Grove Blvd
311864	Off Ramp		F	5	N	11.877	12.18	Laguna Blvd
312133	Mainline	10	A	5	N	12.037	12.18	Laguna Blvd
311847	On Ramp		N	5	N	12.19	12.18	Laguna Blvd
313159	Mainline	12	B	5	N	17.185	12.97	Beach Lake Rd
312132	Mainline	8	A	5	S	10.286	10.89	Elk Grove Blvd
311831	On Ramp		N	5	S	10.882	10.89	Elk Grove Blvd
311832	Off Ramp		F	5	S	11.057	10.89	Elk Grove Blvd
314632	Mainline	10	A	5	S	12.037	12.97	Beach Lake Rd
313824	Mainline	409	A	50	E	.35	.7	EB On-Ramp WB80
313671	Mainline	225	B	50	E	R2.131	R1.9	59th St
312098	Mainline	422	B	50	E	L2.43	L2.38	28th St
313780	Mainline	410	B	50	E	2.477	1.9	Capitol Ave.
314566	On Ramp		N	50	E	2.807	R3.629	SB Howe
314567	Off Ramp		F	50	E	3.396	R3.629	SB Howe
314560	On Ramp		N	50	E	3.629	R3.88	NB Howe/Power Inn
314559	Mainline	228	A	50	E	R3.674	R3.88	NB Howe/Power Inn
313753	Mainline	230	A	50	E	R5.936	R5.7	Manlove POC
314711	Off Ramp		F	50	E	7.509	R7.509	SB Bradshaw Rd.
314726	On Ramp		N	50	E	7.672	R7.67	SB Bradshaw Rd.
314668	Mainline	232	A	50	E	R7.746	R7.854	NB Bradshaw Rd
314666	On Ramp		N	50	E	7.855	R7.855	NB Bradshaw Rd
314536	Mainline	234	A	50	E	R10.919	R11.112	W. of Zinfandel
314291	On Ramp		N	50	E	12.655	12.6	NB Sunrise Blvd.
314297	On Ramp		N	50	E	12.656	12.4	SB Sunrise Blvd.
313056	On Ramp		N	50	E	15.816	R15.8	NB Hazel Ave.
313054	On Ramp		N	50	E	15.817	15.641	SB Hazel Ave.
313606	Mainline	313	A	50	E	17.008	17.86	Iron Point Rd.
314380	On Ramp		N	50	E	21.616	21.56	SB Scott Rd O.C.
313822	Mainline	409	A	50	W	.35	.7	WB On-Ramp WB80

Figure 4. Matching report that shows the association between the Census Station IDs and the PeMS Stations IDs.

Figure 4 is a matching report for Caltrans District 3. We can generate this report for any district or for any freeway. In this case it shows that we were able to match 47% of the mainline stations in PeMS to Traffic Census Stations. It should be noted that there are typically many more stations providing data to the TMC than to the Traffic Census Program (hence the percentage matched will always be low). The table below the pie charts gives the list of PeMS stations, mainline, on-ramps and off-ramps that match to Traffic Census Stations. In addition to looking at raw tables users can see all of the matched stations on a map, as shown in Figure 5 below.

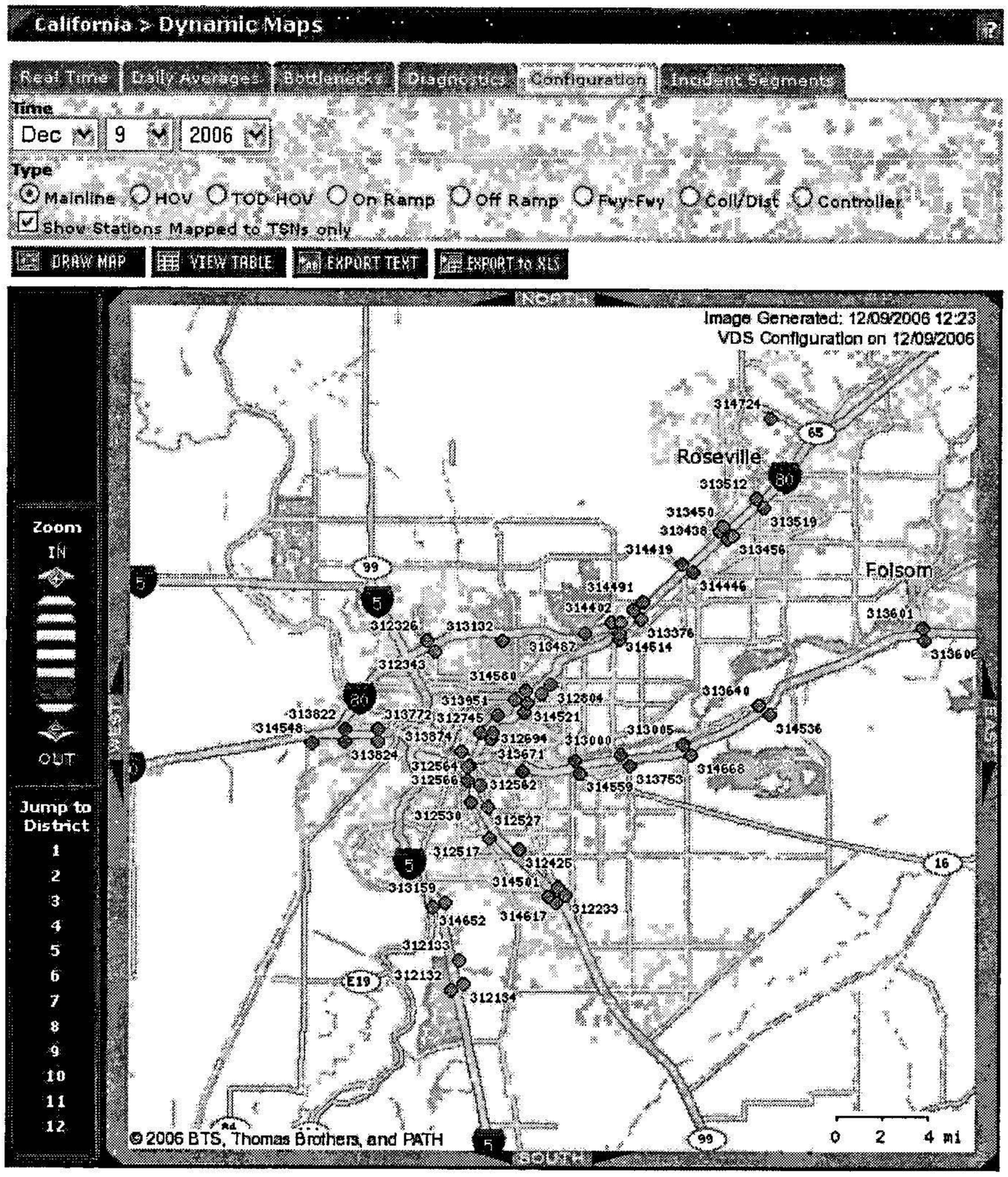
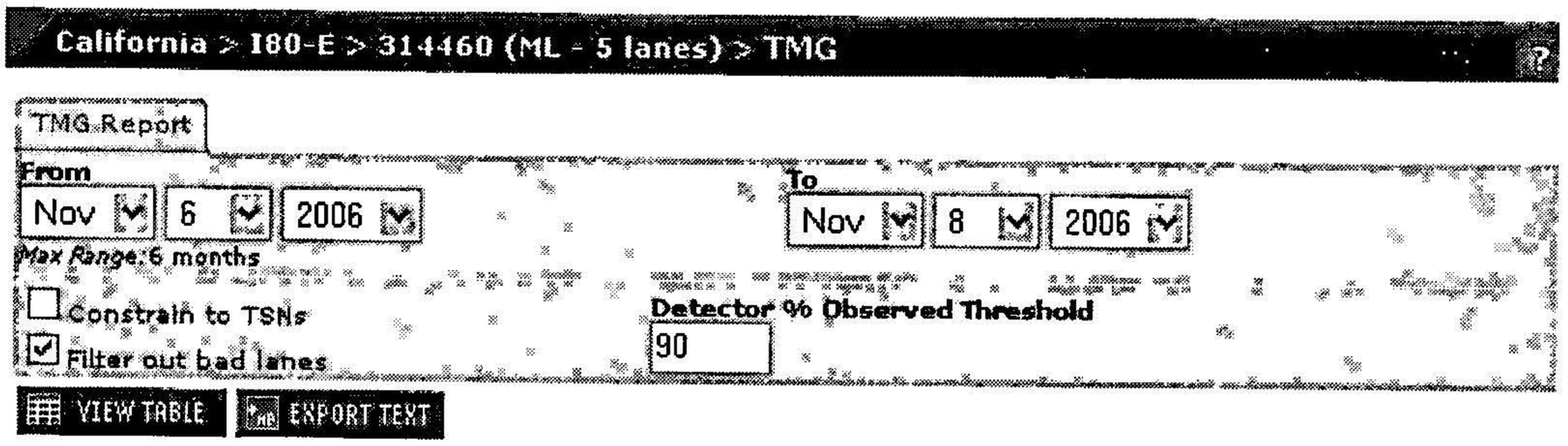


Figure 5. Map showing mainline PeMS stations that are matched to Traffic Census Group stations.

That map shows only the PeMS mainline stations that are matched to Traffic Census stations.

The TMG format itself is a fixed-width format without separating spaces or commas. Hence it's rather difficult to decipher visually. Nevertheless, the formatted TMG report is presented on a web page for verification purposes. In the web-based report users can filter out data which has been heavily imputed as well as data where the lane detector is simply bad. Figure 6 is a screen shot of the TMG report for a single VDS stations over three days. You can see that we report the flow for each lane for each hour of the day.



Record Type	FIPS State Code	Functional Class	Site ID	0	Direction	Lane	Year	Month	Day	DOW	1	2	3	4	5	6	7
3	06	00	03---	0	3	1	06	11	06	2	00022	00013	00004	00009	00019	00111	003
3	06	00	03---	0	3	2	06	11	06	2	00105	00057	00027	00046	00107	00433	015
3	06	00	03---	0	3	3	06	11	06	2	00170	00081	00052	00082	00158	00494	012
3	06	00	03---	0	3	4	06	11	06	2	00185	00102	00091	00110	00182	00425	009
3	06	00	03---	0	3	5	06	11	06	2	00215	00164	00120	00120	00190	00330	006
3	06	00	03---	0	3	1	06	11	07	3	00037	00019	00005	00005	00014	00117	003
3	06	00	03---	0	3	2	06	11	07	3	00135	00091	00035	00052	00083	00444	014
3	06	00	03---	0	3	3	06	11	07	3	00195	00140	00074	00080	00139	00493	011
3	06	00	03---	0	3	4	06	11	07	3	00192	00127	00108	00119	00161	00457	009
3	06	00	03---	0	3	5	06	11	07	3	00237	00190	00160	00167	00212	00367	006
3	06	00	03---	0	3	1	06	11	08	4	00057	00029	00010	00019	00009	00121	003
3	06	00	03---	0	3	2	06	11	08	4	00123	00080	00038	00048	00081	00412	014
3	06	00	03---	0	3	3	06	11	08	4	00163	00091	00066	00066	00138	00458	010
3	06	00	03---	0	3	4	06	11	08	4	00211	00144	00099	00108	00173	00435	009
3	06	00	03---	0	3	5	06	11	08	4	00224	00178	00145	00161	00210	00353	005

Figure 6. Sample web-report of TMG format for a single VDS.

This feature is now fully functional within PeMS.

Task 4 Additional PeMS User Interface Requests

We receive a continuous stream of suggestions and requests for features to add to PeMS from various Caltrans engineers and Agency Partners. In this task we have implemented a few of the recent requests. We provide a figure for each plot implemented.

The first new feature is a plot of congestion spreading, as given in Figure 7. This plot shows the amount of time during the AM or PM shift that a single location spent in congestion. This is similar to a peak hour plot, but it's a measurement of the actual duration of congestion, instead of the amount of traffic during a certain time of day. The raw data is simply the amount of time spent per day with speeds under the selected threshold speed. We also provide to the user the choice of aggregating the data up to a weekly or monthly average. When doing so we then present the minimum, mean and maximum values over the aggregation period. Figure 7 is a plot of the weekday AM congestion with a granularity of a month over 2006 for a detector in Caltrans District 3 on SR-99N, which is south of Sacramento. The northbound direction is the morning commute direction. We can see that during the months of February-June there was significantly more congestion than during the summer and fall months.

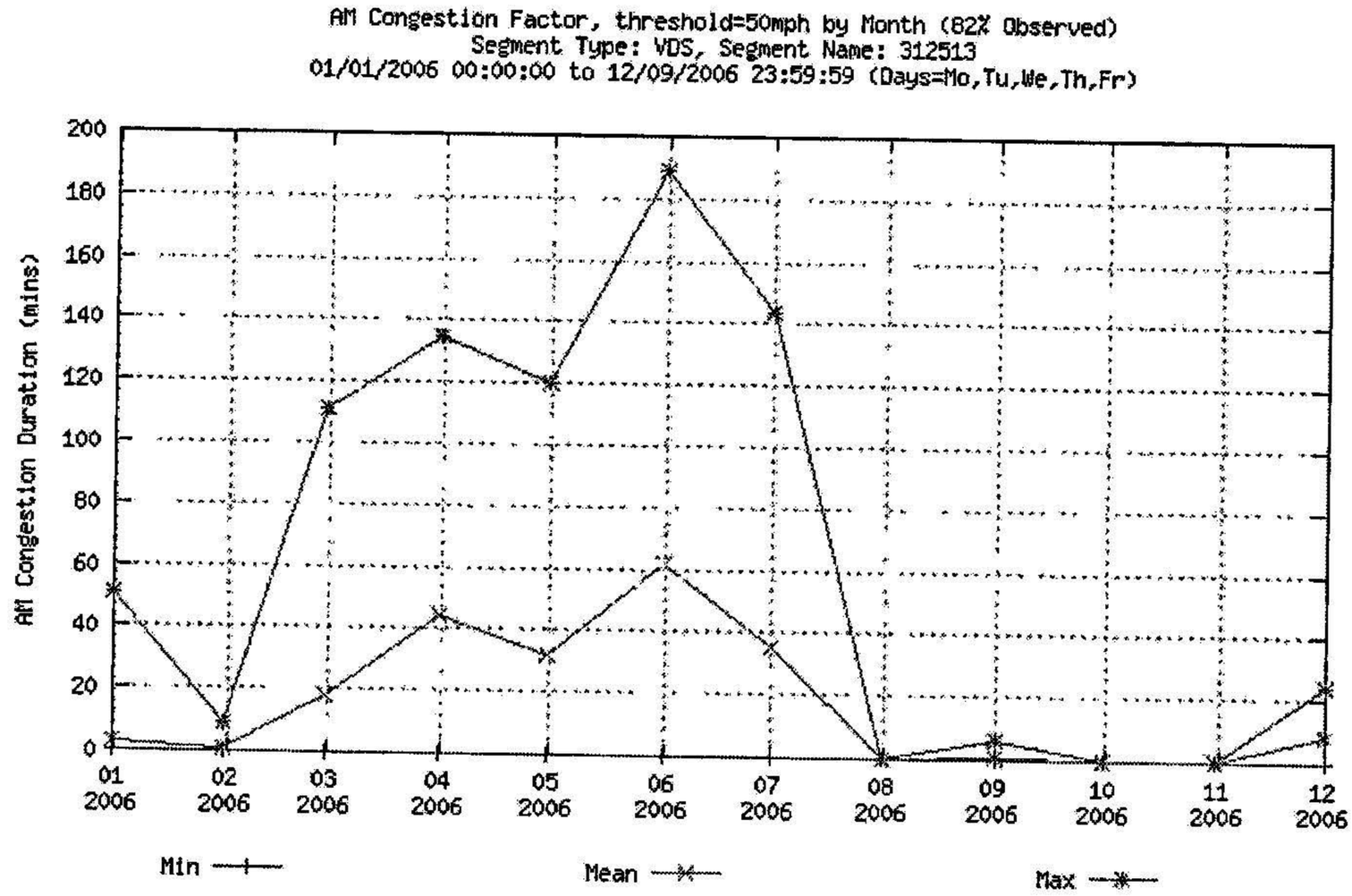


Figure 7. Plot of congestion spreading.

The second request was that we provide the users with the option to put a trend line on the AADT plot over years. This has now been implemented as shown in Figure 8 below. The trend line is simply a straight-line fit to the median of the ADT for each year. We present the user with the resulting equation for the fit line and they can see the projected values in a table below the plot on the web page.

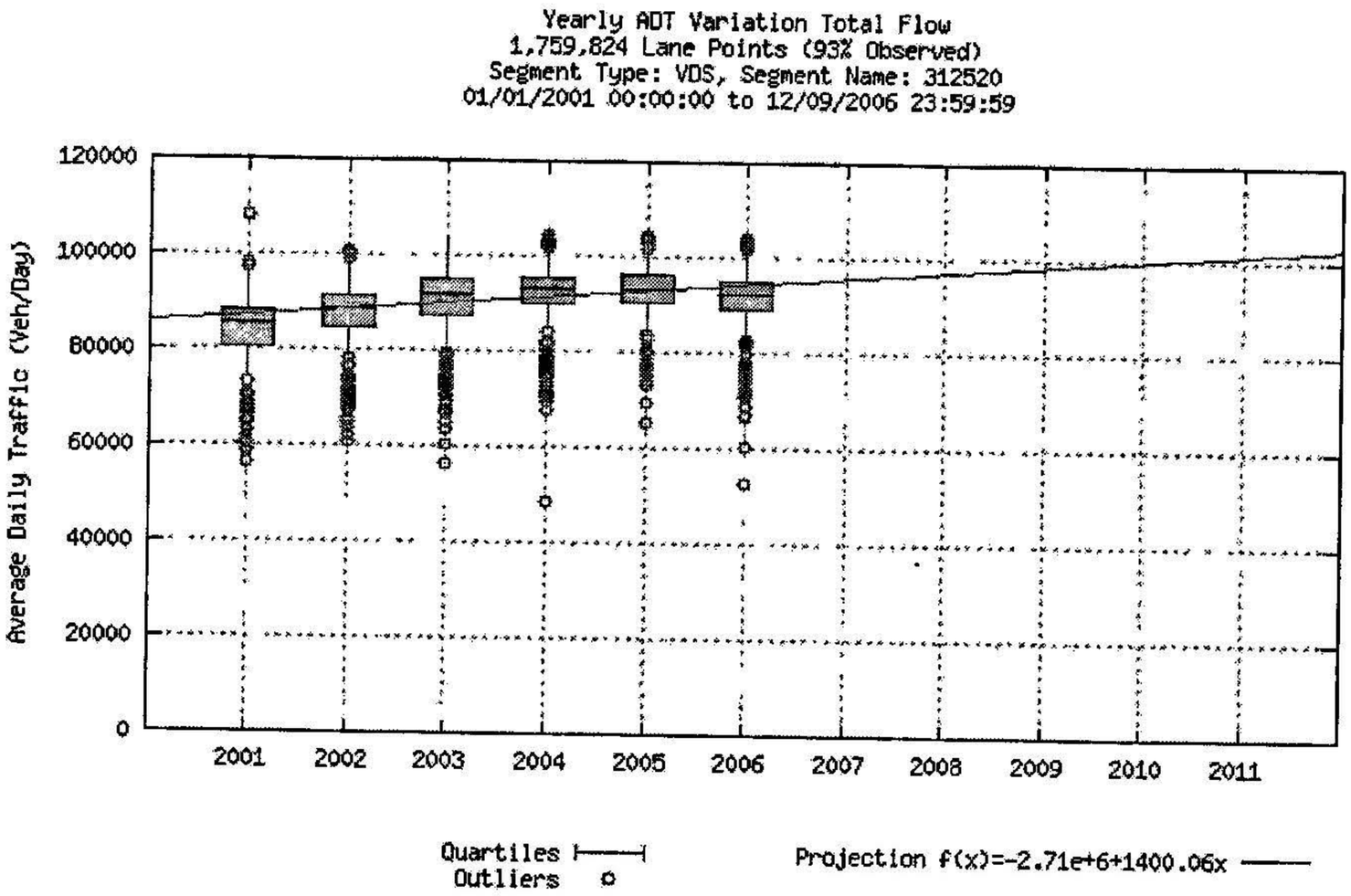


Figure 8. Plot of AADT with trend line.

The third request was to expand the dashboard view. PeMS started off with relatively simple dashboards that only provided for a few measures. In this sub-task we extended the dashboards to have additional types of plots on them. Figure 9 below shows the current incarnation of the dashboards with performance measures on the top row, causes of congestion on the middle row, and route travel time analysis on the bottom row.

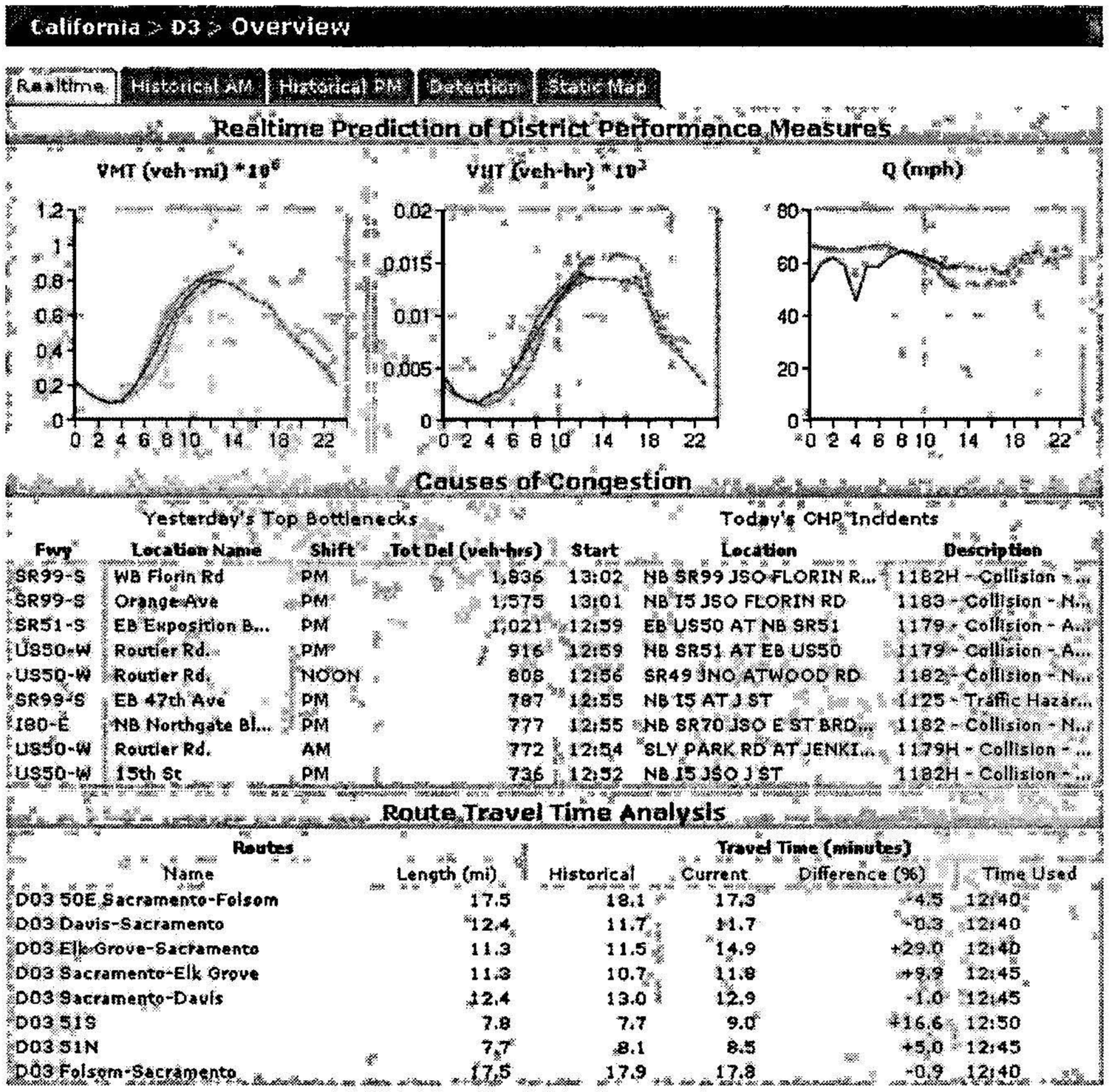


Figure 9. Current version of the PeMS dashboard for D3.

The fourth request was to be able to see individual days of data when showing the time of day plots. Originally PeMS only showed descriptive statistics (i.e.: mean, median, min, max, etc). Figure 10 shows a plot of hourly flow for 8 days from one detector.

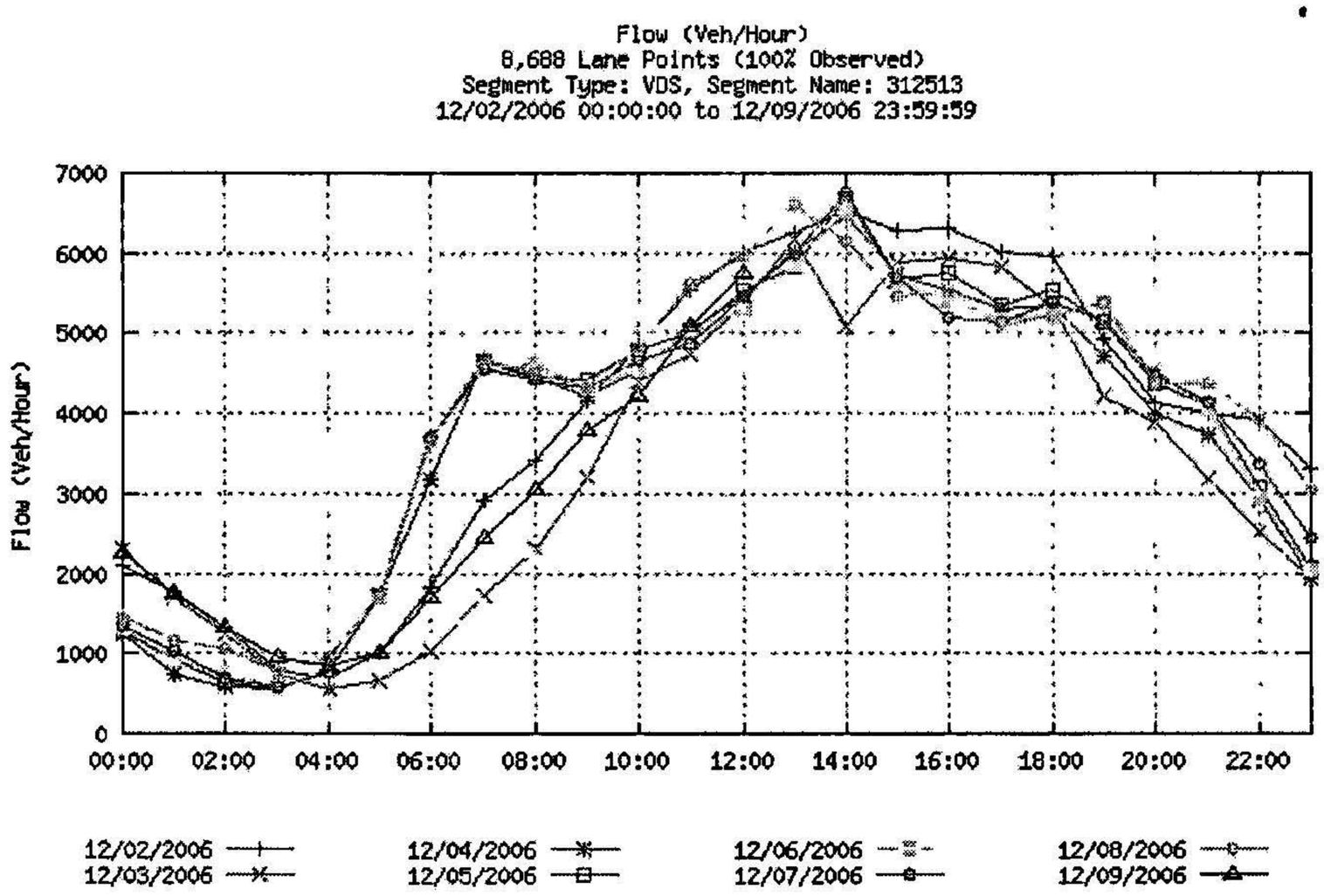
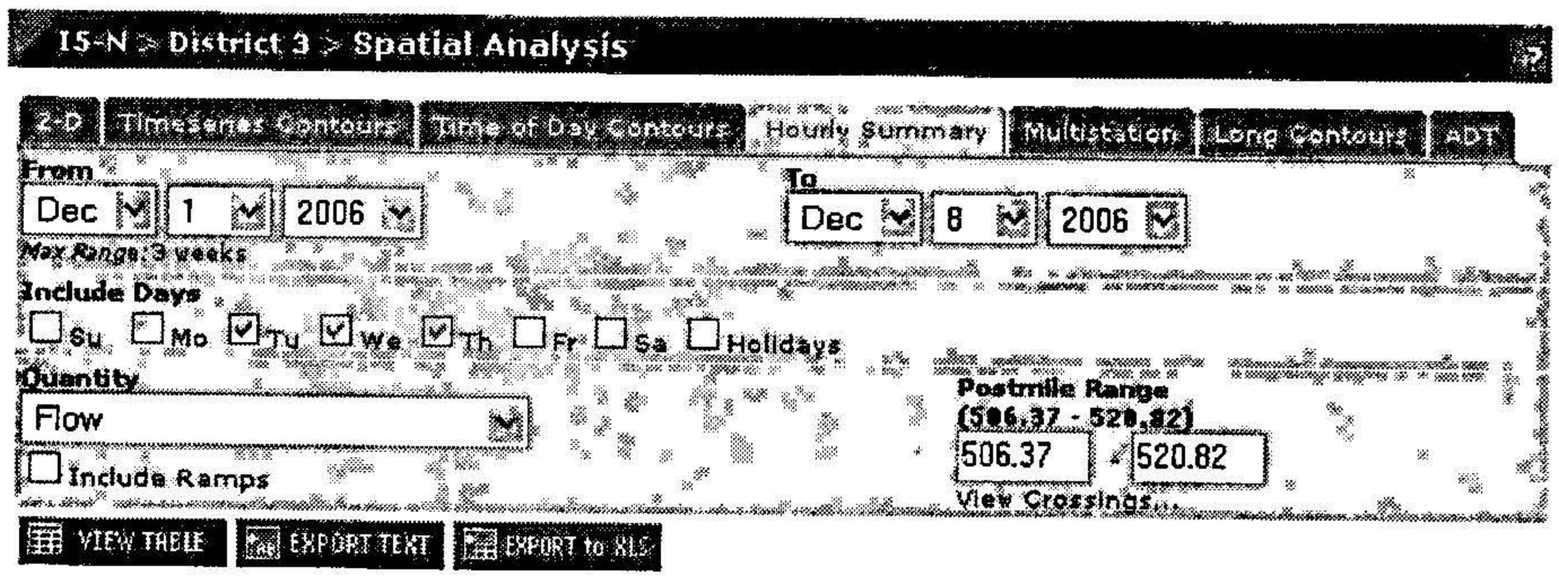


Figure 10. Plot showing individual days of flow.

The final request was to extend the hourly traffic volumes table to be able to sum up values over multiple days and to do this for different quantities. We've extended this table, as shown in Figure 11, to let users select a range of days and whichever quantity they are interested in.



CA PM	VDS	Name	Type	% Observed	00	01	02	03	04	05	06	
11.09	312134	Elk Grove Blvd	Mainline	99.9	786	666	596	713	1,420	3,171	6,339	5
12.18	312133	Laguna Blvd	Mainline	100.0	882	723	659	866	1,849	4,468	9,871	8
12.97	313159	Beach Lake Rd	Mainline	100.0	1,178	835	768	1,008	2,369	5,892	14,468	13
16.048	314876	EB Pocket Rd	Mainline	100.0	1,051	799	733	939	2,257	5,492	13,069	11
16.25	314886	WB Pocket Rd	Mainline	100.0	1,073	817	752	981	2,364	5,829	14,244	12
16.78	314768	S Land Park Dr	Mainline	100.0	1,250	928	856	1,126	2,251	5,388	12,626	13
17.26	314899	EB Florin Rd	Mainline	100.0	1,113	848	802	1,052	2,617	6,670	15,704	13
17.46	314909	WB Florin Rd	Mainline	75.0	1,336	1,029	977	1,269	2,924	7,294	17,112	15
18.21	314780	Gloria Dr	Mainline	98.8	1,361	1,115	956	1,271	2,770	6,791	16,253	16
18.68	314923	43rd Ave.	Mainline	98.8	1,273	962	884	1,247	3,114	7,492	18,501	18
19.335	314936	Seamas Ave.	Mainline	100.0	1,360	1,000	959	1,321	3,381	8,786	21,095	22
19.88	314792	25th Ave.	Mainline	75.0	2,378	1,948	1,740	2,099	3,768	7,828	15,253	15
20.68	314968	Sutterville Rd	Mainline	100.0	1,399	1,067	1,007	1,392	3,472	8,883	21,152	23
21.3	314848	10th Ave.	Mainline	100.0	1,603	1,075	1,115	1,400	3,000	7,577	16,609	20
21.8	314835	Vallejo Way	Mainline	100.0	1,636	1,178	1,037	1,407	3,331	6,195	12,107	11
22.69	314808	W St.	Mainline	100.0	1,055	757	650	855	1,262	2,998	5,723	8
23.25	314955	P St.	Mainline	100.0	2,214	1,660	1,580	2,040	4,488	8,972	17,851	21
23.59	314982	L St.	Mainline	99.7	2,080	1,406	1,316	1,675	4,024	8,160	16,002	18
23.9	315017	I St.	Mainline	65.4	2,641	1,979	2,191	2,594	4,304	8,712	14,786	18
24.278	314821	Jibboom St.	Mainline	100.0	2,571	1,734	1,738	1,782	3,269	8,000	15,840	22
25.451	315054	WB Garden Highway	Mainline	100.0	2,230	1,574	1,412	1,647	3,954	7,796	14,488	17
Total					32,470	24,102	22,728	28,484	62,188	142,414	309,893	330

Figure 11. Table showing total hourly flow over Tu-Th for all mainline detectors on I5-N in D3.

All of these features have been implemented in PeMS and are now on the live site.

Task 5 PeMS Data Server

In this project we implemented a system to provide bulk PeMS data to the public, researchers and consultants. The main way for users to interact with PeMS is through the web pages. These are intended for users that want to see plots of data and various reports for individual detectors or corridors. They were never intended for users that want to extract large amounts of data in order to run their own analyses. To address this need we have placed all of the PeMS data in compressed flat files in a variety of temporal granularities. We have also put in place a process to automatically export the latest data to augment this data set.

This task involved three steps. First, we needed to configure an additional amount of disk space to hold all of the exported data. We are using the disks that we purchased when the project first started to host this data. For the live data we have transitioned to new, faster disks. We have rearranged the old disks into the appropriate RAID volumes to be able to handle this data.

Second, we needed to export all of the current data to compressed flat files. We export the data to the following formats:

1. Raw data, 30-second, lane-by-lane data of flow and occupancy for every detector in the district. One file for each district per day.
2. 5-minute, lane-by-lane data of flow, occupancy and speed for every detector in the district. One file for each district per day.
3. 1-hour, station (VDS) data of flow, occupancy and speed for every detector in the district. One file for each district per month.
4. 1-day, station data of flow for every detector in the district. One file for each district per month.

Users can download the data by navigating through the web site and selecting the appropriate file. We keep track of which users have downloaded which data sets through the standard web request tracking mechanisms.

The last task of this project was to write the automated scripts that export the new data every night.

Task 6 Web-Based Configuration Management

In this project we enhanced the detector configuration management functionality of the current PeMS systems so that the district personnel can perform all of the steps to update their configurations via the web site without interacting with PeMS system administration personnel. In previous versions of PeMS, the constant flux of information about the detectors was managed through a mixture of automated and manual steps.

The detailed steps for a District to update their configuration under this new scheme are as follows. First, a District determines themselves that they need to update the configuration in PeMS. They would know this because they know that they've changed something recently; either installing or removing detectors. Second, the District contact person packages their configuration into a dump file. Each district already has the ability to create a dump file from their own system.

Third, the District person opens a web page inside of PeMS in their browser. The current version of this page is given in Figure 12. We'll refer to this collection of web pages in PeMS as the Configuration Management Interface (CMI). The web page presents the user with a form that they can use to upload their configuration. Access to this page is controlled by an extensive permission system inside of PeMS. Users in each district are assigned as managers of their district and only they are allowed to upload and manage configurations.

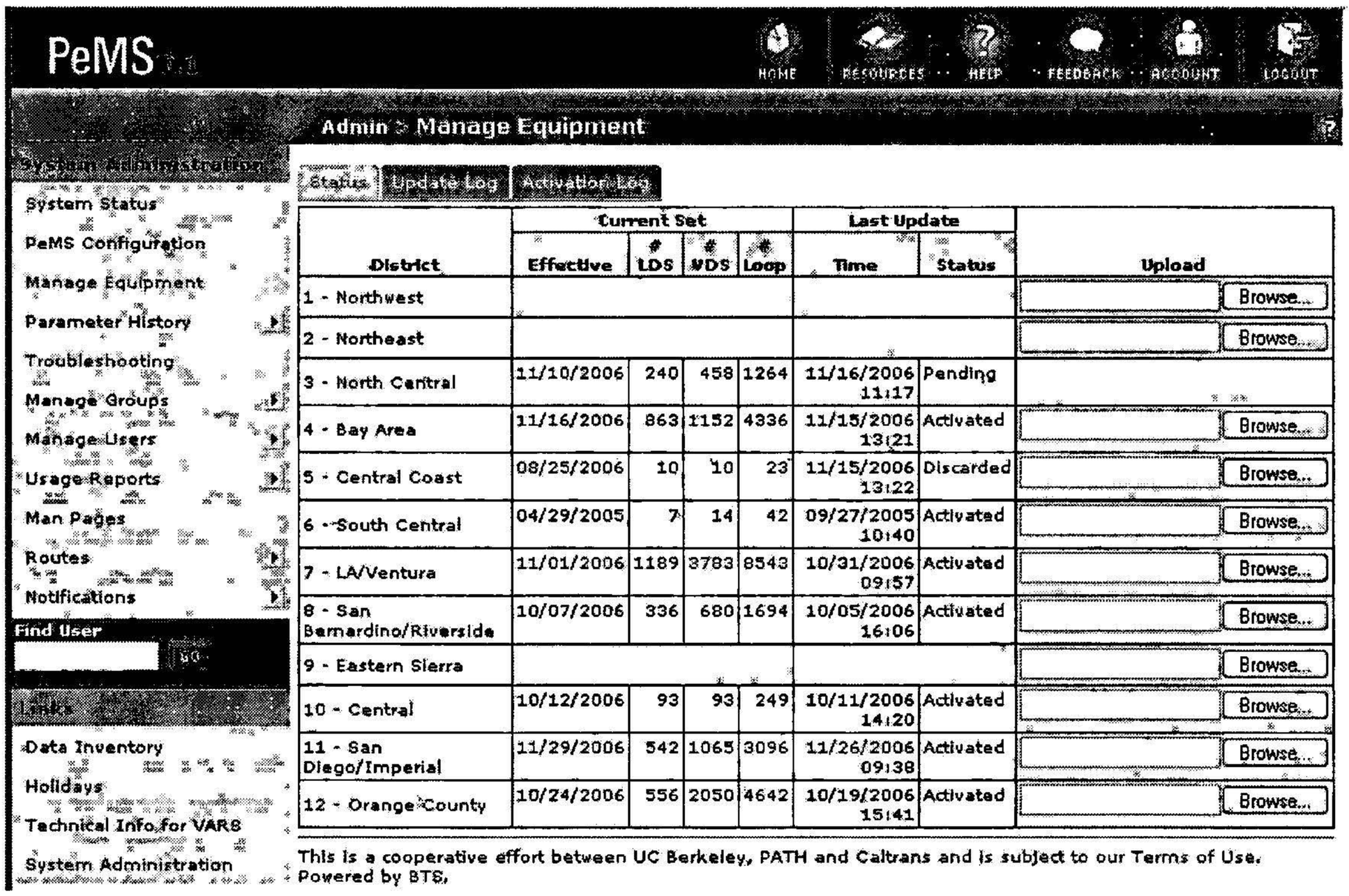
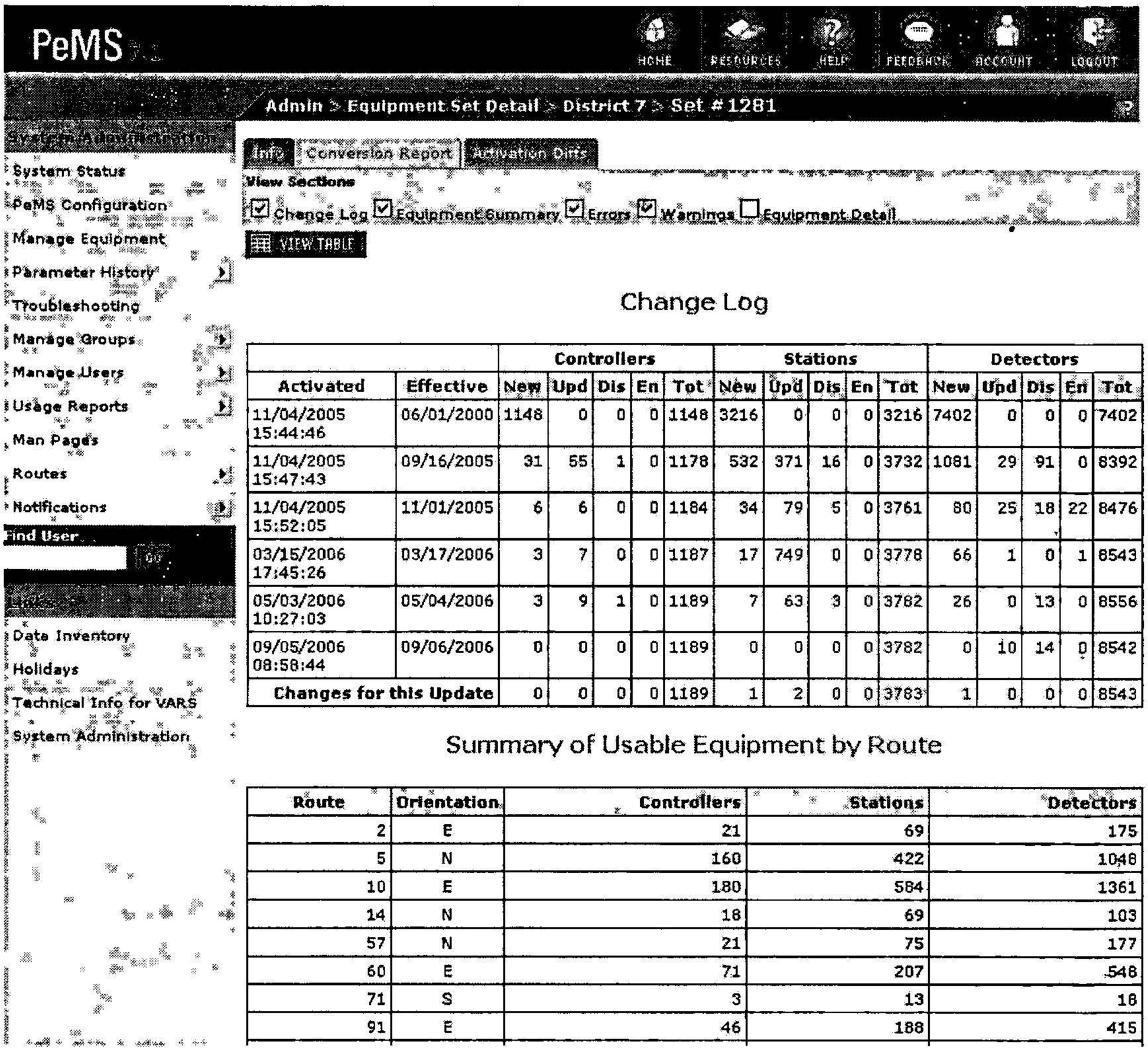


Figure 12. Detector configuration management starting page. Users can upload a configuration for a district if they have the permissions to do so.

Fourth, the CMI receives the configuration from the District and performs the standard PeMS consistency checking. The CMI presents the user with the results of the consistency checking process. In addition, users can see all of the previous configurations that they have uploaded.

Fifth, the user can now review all of the results and determine if the configuration is good or not, as shown in Figure 13. Further down on that page (which is not visible in the screen shot) there are explanations as to why certain detectors failed consistency checks as well as links to relevant metadata that can assist in explaining the failure. If the user decides that the errors warrant changing the configuration then they can do so and resubmit the new configuration in step (2). All uploaded configurations are available to see, but aren't activated in PeMS yet. They are essentially in a staging area.



		Controllers					Stations					Detectors				
Activated	Effective	New	Upd	Dis	En	Tot	New	Upd	Dis	En	Tot	New	Upd	Dis	En	Tot
11/04/2005 15:44:46	06/01/2000	1148	0	0	0	1148	3216	0	0	0	3216	7402	0	0	0	7402
11/04/2005 15:47:43	09/16/2005	31	55	1	0	1178	532	371	16	0	3732	1081	29	91	0	8392
11/04/2005 15:52:05	11/01/2005	6	6	0	0	1184	34	79	5	0	3761	80	25	18	22	8476
03/15/2006 17:45:26	03/17/2006	3	7	0	0	1187	17	749	0	0	3778	66	1	0	1	8543
05/03/2006 10:27:03	05/04/2006	3	9	1	0	1189	7	63	3	0	3782	26	0	13	0	8556
09/05/2006 08:58:44	09/06/2006	0	0	0	0	1189	0	0	0	0	3782	0	10	14	0	8542
Changes for this Update		0	0	0	0	1189	1	2	0	0	3783	1	0	0	0	8543

Route	Orientation	Controllers	Stations	Detectors
2	E	21	69	175
5	N	160	422	1048
10	E	180	584	1361
14	N	18	69	103
57	N	21	75	177
60	E	71	207	548
71	S	3	13	18
91	E	46	188	415

Figure 13. Configuration management page showing conversion report for a single configuration.

Sixth, once the user decides to use a particular configuration then they can simply click a button to active the configuration within PeMS, as shown in Figure 14. On the activation screen, users can enter a small note about the configuration – something explaining why the configuration update was made, or why the errors were ignored, etc.

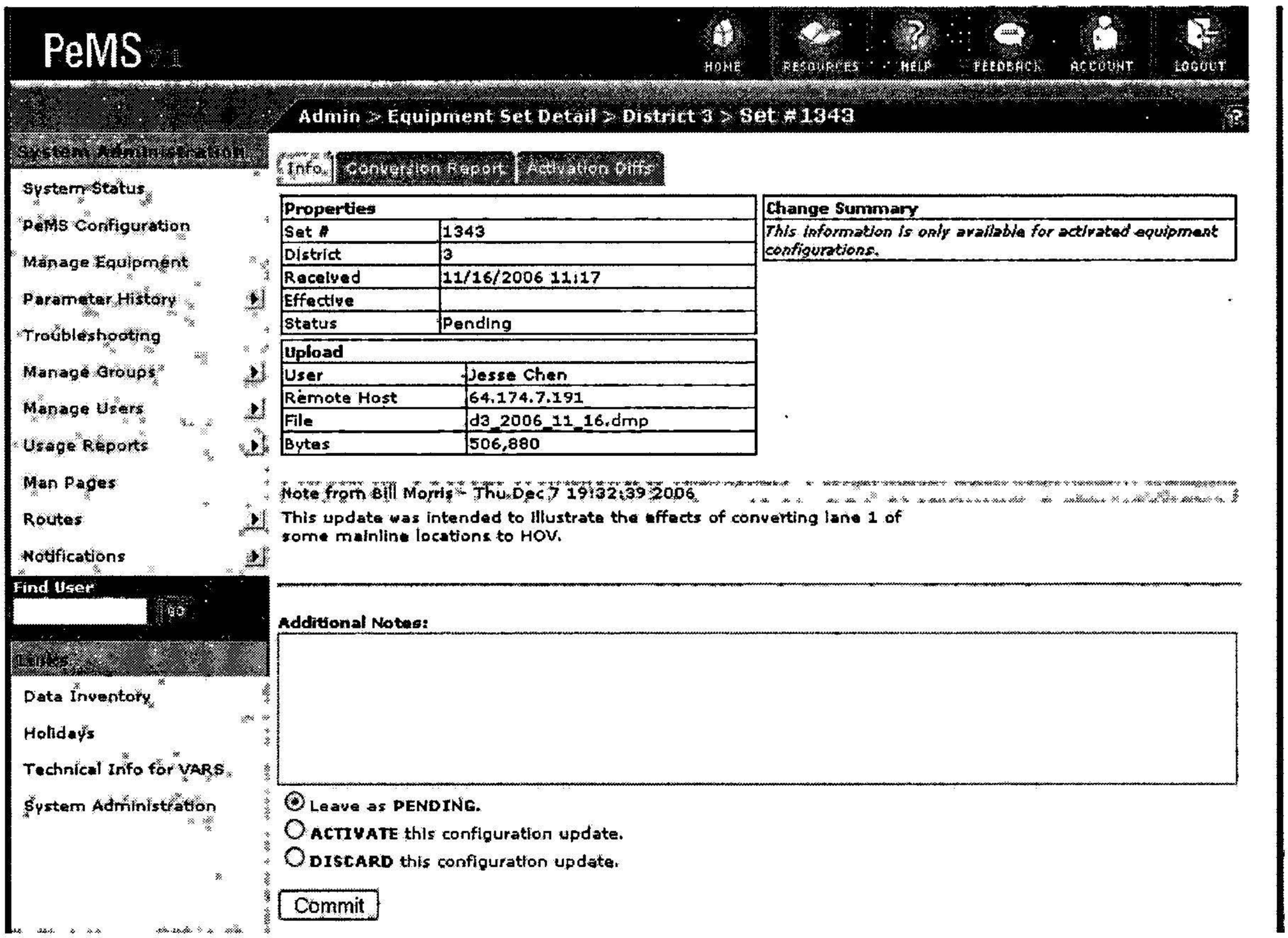


Figure 14. Configuration management screen where user can activate the configuration.

Once a configuration is activated PeMS automatically notifies the data collection infrastructure to start collecting data and PeMS itself incorporates this configuration as the active one.

With this new approach there is no longer any interaction between the District contact person and the managers of the PeMS system. All of the steps are taken via the web and are owned by the District contact person.

Conclusion

The collection of work items with this project reflect a number of operational tasks and feature requests that came up during the course of the year. By quickly implementing these we are able to keep PeMS up to the standards expected by Caltrans.

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