

# Overflow Intelligent Early Warning System Based on BP Neural Networks

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**Abstract:** Overflow is one of the most serious drilling accidents that affect the safety of drilling construction. The analysis of integrated logging parameters and the judgement of overflow situation in China still remain in the stage of "manual judgement" and "threshold warning". Based on this, we propose the method of combining the real time measurement information of comprehensive logging instrument with artificial intelligence technology, and design a BP neural network based intelligent early warning software system using SQL Server 2008 database management platform and C# program development language. Through the experimental test, the system runs well, the timeliness of overflow early warning is good, the accuracy of early warning results is high, and it can meet the needs of field application, and it can provide effective technical support for the field overflow early warning, and it has a better prospect of field application.

**Keywords:** Overflow warning, Integrated logger, BP neural network.

## 1. Introduction

Overflow is one of the most serious drilling accidents that affect the safety of drilling construction[1]. If some kind of alarm or warning can be given at the early stage of overflow, it is of great significance for preventing and controlling the development of overflow, preventing blowout or even blowout out of control, and minimising losses.

At present, the foreign research trend in overflow early warning is, on the basis of the existing overflow detection equipment, constantly explore new overflow detection equipment, and combined with the cutting-edge artificial intelligence technology, explore new, able to carry out automated, intelligent comprehensive analysis and judgement of the measurement information overflow intelligent early warning methods. The intelligent early warning methods used abroad mainly include the early overflow warning method based on Bayesian decision framework[2], the overflow warning method based on fully connected network[3][4][5] and the overflow warning method based on long and short-term memory network[6][7] and so on.

In recent years, domestic researchers have also begun to try to introduce some artificial intelligence methods for overflow early warning, Sun Ting proposed a data-driven real-time identification method for drilling conditions based on support vector machine, established several intelligent identification models, and verified the accuracy of the models by using the logging data of four wells, and the identification results are basically consistent with the actual working conditions[8]. Shi Xiaoyan used a data-driven machine learning algorithm-random forest method to make real-time identification judgement on overflow and leakage[9]. Tu Siyu proposed an intelligent identification and classification study of abnormal working conditions in the downhole environment based on the use of deep learning methods. By analysing the main influencing factors of normal operation and operation of equipment, a data set of abnormal working conditions in downhole environment was constructed, and based on the InceptionResnet V2 model using the layer freezing method, the fully-connected model was re-trained, and experimental

comparative analysis was carried out through different migration strategies[10]. Gao Xiaorong designed and developed an intelligent diagnosis and processing system for downhole complex situations and accidents based on instance reasoning technology based on the cognition and decision-making process of drilling experts when downhole complex situations and downhole accidents occur[11]. Compared with foreign countries, the domestic research on overflow intelligent early warning started later, although the domestic overflow intelligent early warning has also done a certain amount of research work, but the domestic application of integrated logging instrument for overflow early warning method basically stays in the "artificial judgement" and "threshold warning" stage. However, the domestic method of applying integrated logger for overflow warning basically stays in the stage of "manual judgement" and "threshold warning". There is a lack of corresponding and mature overflow intelligent early warning system based on real-time measurement information of integrated logger, which greatly limits the application of integrated logger in overflow early warning.

Therefore, this paper proposes an overflow intelligent early warning method that combines the real-time measurement information of comprehensive logger with artificial intelligence technology. Based on SQL Server 2008 database management platform and C# programme development language, the overflow intelligent early warning software system based on BP neural network is completed.

## 2. Study of Overflow Characterisation Parameters and Their Characterisation Laws

From the analysis of the mechanism of overflow occurrence, it can be seen that when overflow occurs, due to the continuous influx of formation fluids into the wellbore, the bottomhole pressure is smaller than the formation pressure, causing changes in pump pressure and mud outlet flow rate. At the same time, mud parameters such as drilling fluid temperature, density, conductivity, mud pool volume, and

engineering parameters such as pumping speed, suspended weight, and drilling speed, will also change. Therefore, through real-time monitoring of the changes in these drilling parameters, it is possible to timely determine whether formation fluid intrusion has occurred downhole, and real-time overflow warning can be achieved.

Through a review of the literature [12]-[17] and a large amount of information from the field, the characterisation parameters that are closely related to overflow and their characterisation laws are finally summarised as shown in Table 1.

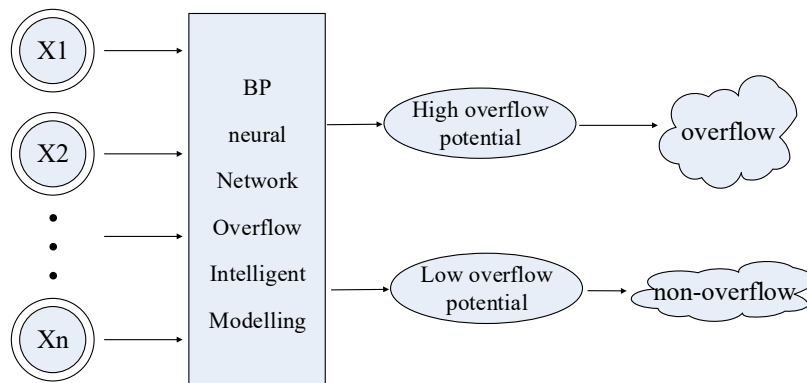
**Table 1.** Overflow warning characterisation parameters and characterisation patterns

overflow characterisation parameters	overflow characterisation laws	note
standpipe pressure	varying	wave jump change
drill time	lower	null
pool volume	raise	null
export drilling fluid flow rate	raise	relative to inlet drilling fluid flow
export drilling fluid conductivity	varying	relative to inlet drilling fluid
export drilling fluid density	lower	relative to inlet drilling fluid density
export drilling fluid temperature	raise	relative to inlet fluid temperature
aerometric total hydrocarbon	varying	no change in pure water intrusion
C1 component content	varying	no change in pure water intrusion

### 3. Intelligent Early Warning Model for Overflow Based on BP Neural Network

To change the traditional overflow early warning method based on manual judgment and threshold warning, it is necessary to comprehensively use information acquisition technology, computer technology, artificial intelligence

technology, etc. to carry out automated and intelligent comprehensive analysis and comprehensive judgement on the real-time measurement information of comprehensive logger, so as to realize the overflow intelligent early warning. The flow of overflow intelligent early warning based on real-time measurement information of comprehensive logger is shown in Figure 1. Where X1-Xn represents the change amount of overflow characterisation parameters that can reflect the change of overflow characterisation parameters.



**Figure 1.** Overflow intelligent warning process

The BP neural network takes the overflow characterisation parameter changes as input, i.e., the input vector is  $X = (X1, X2, X3, X4, X5, X6, X7, X8, X9)$ ; the two outputs of overflow and non-overflow anomalies are taken as the output parameters of the BP neural network, i.e., the output vector is  $Y = (Y1, Y2)$ ; Sigmoid-type excitation function is selected for the hidden layer, and linear-type excitation function is selected for the output layer.

### 4. Overflow Intelligent Early Warning System Development and Implementation

The design of the overflow intelligent warning software system supporting the integrated logging instrument is based on the overflow intelligent warning model, real-time data

acquisition system and database system, which can complete the seamless connection with the integrated logging instrument and realise the data acquisition of the real-time measurement data of the integrated logging instrument, the real-time monitoring and the intelligent warning in one software system. Each software function module is independent of each other, but also organically combined together.

#### 4.1. Overall system architecture design

The overflow intelligent warning software system supporting the integrated logging instrument is mainly composed of real-time data acquisition module, real-time monitoring module, database management module and overflow real-time intelligent warning module. The overall framework of the system is shown in Figure 2.

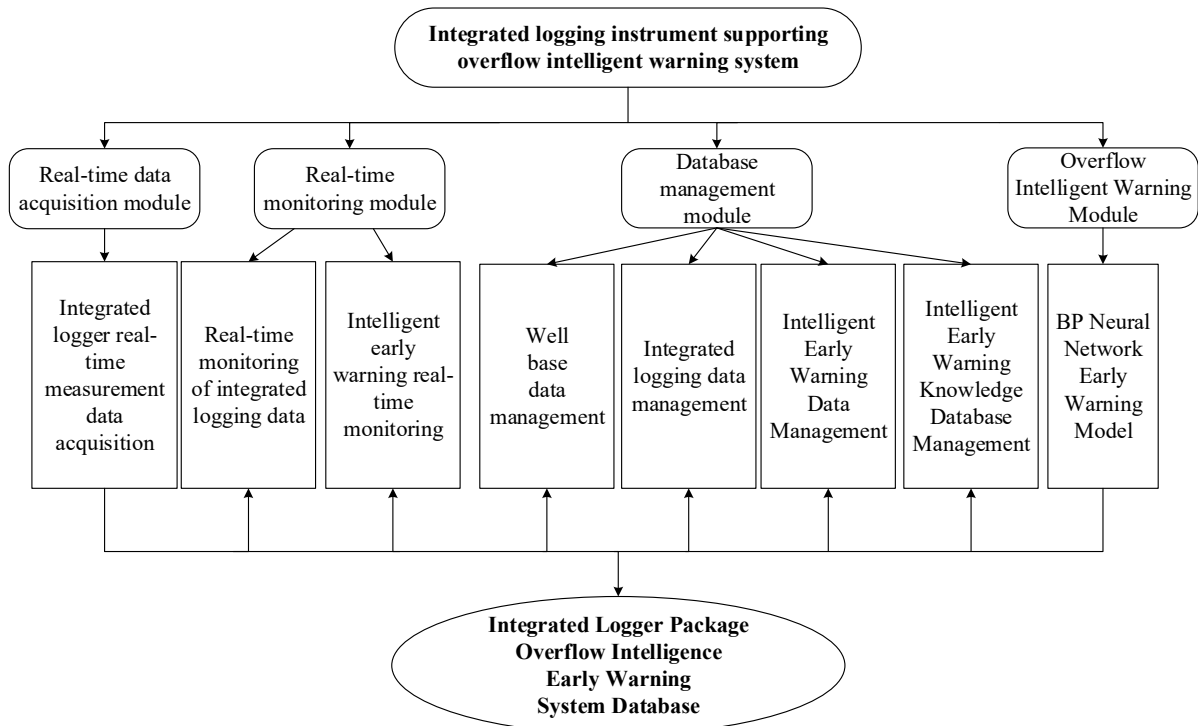


Figure 2. Overall system framework

Among them, the real-time data acquisition module mainly completes the real-time acquisition of the real-time measurement data of the integrated logging instrument, and then realises the seamless connection between the overflow intelligent warning module and the integrated logging instrument; the real-time monitoring module is mainly responsible for the real-time updating and displaying of the real-time acquisition data and the real-time warning results; the database management module is mainly responsible for well basic data management, integrated logging data management, real-time intelligent warning data management and intelligent warning knowledge base data management, etc. The intelligent warning model establishment module is mainly responsible for the establishment of overflow intelligent warning model based on BP neural network.

#### 4.2. System operation architecture design

The overflow intelligent warning system supporting the integrated logging instrument is centred on the database of overflow intelligent warning system built on the SQL Server database platform, real-time measurement data of the integrated logging instrument is collected in real time through the data acquisition system and the real-time collected data is stored in the SQL Server database in real time. Through the client equipped with overflow intelligent warning system to complete the real-time collection of data management, overflow warning data management, real-time monitoring of data collection, real-time overflow intelligent warning based on BP neural network and other functions. The system operation architecture is shown in Figure 3.

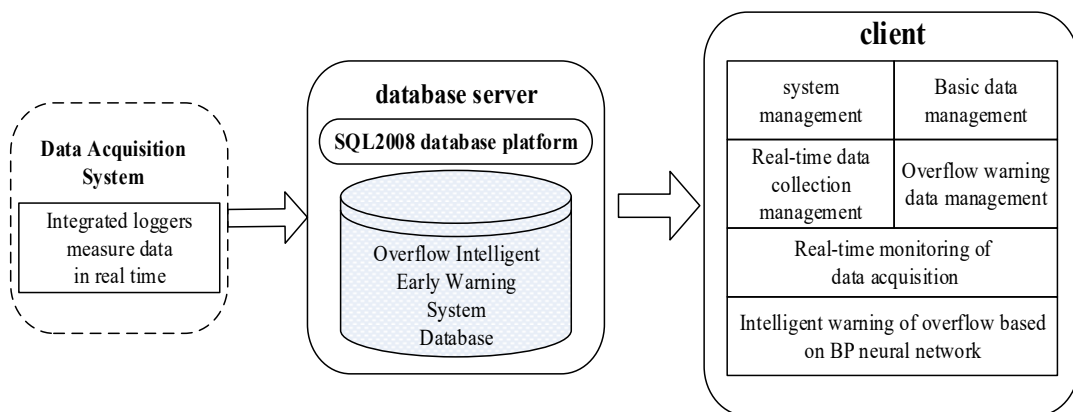


Figure 3. System operation architecture

#### 4.3. System Logical Architecture Design

Through the demand analysis and research on the overflow

intelligent warning software system supporting the integrated logging instrument, the logical architecture of the designed

overflow intelligent warning system supporting the integrated logging instrument includes the following: real-time data acquisition module, integrated logging data real-time monitoring module, integrated logging data history viewing module, database management module, overflow intelligent

warning module, and overflow intelligent warning model building module. This section only shows the overflow intelligent warning module based on BP neural network, and the logical architecture of this module is shown in Figure 4.

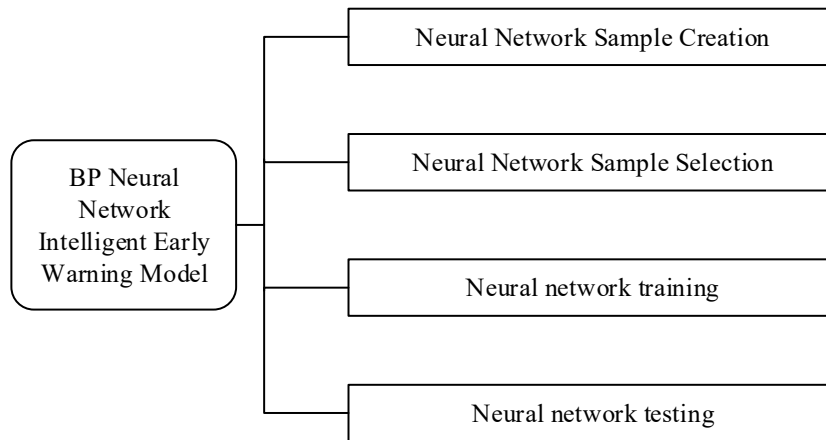


Figure 4. Overflow intelligent warning model module

#### 4.4. System Data Architecture Design

The data architecture of the integrated logger supporting overflow intelligent warning system designed in this paper mainly takes SQL Server database management platform as

the data management and storage medium. It mainly consists of four parts: system basic database, real-time acquisition database, warning knowledge base and warning result base. The data architecture of the overflow intelligent warning system for integrated logger is shown in Figure 5.

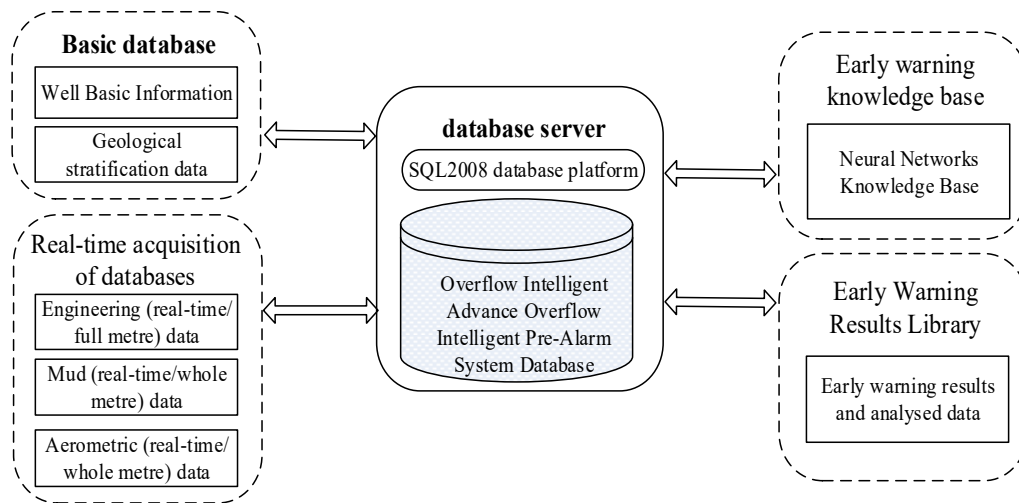


Figure 5. System Data architecture

#### 4.5. Implementation of Overflow Intelligent Early Warning Module Based on BP Neural Networks

The BP neural network based overflow intelligent early warning model building module is designed and developed to complete the production of training samples and test samples, BP neural network training and testing, as well as saving the weights and threshold matrices that meet the test requirements, etc. The sample data are mainly imported from database and Excel, and the weights and threshold matrices are saved in .txt files. The main interface of BP neural network training, the sample selection interface, and the error convergence curves are shown in Fig. 6~Fig. 8, respectively.

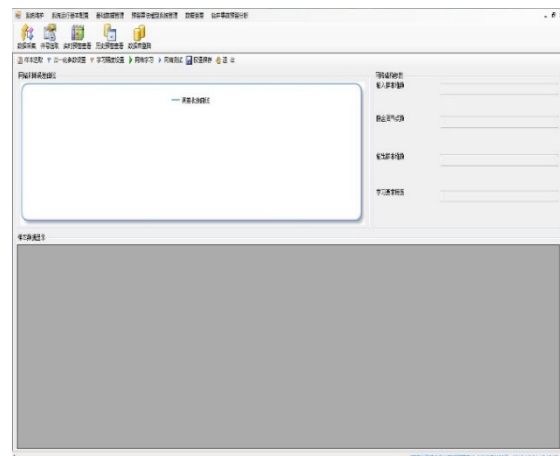


Figure 6. Main interface of BP neural network training

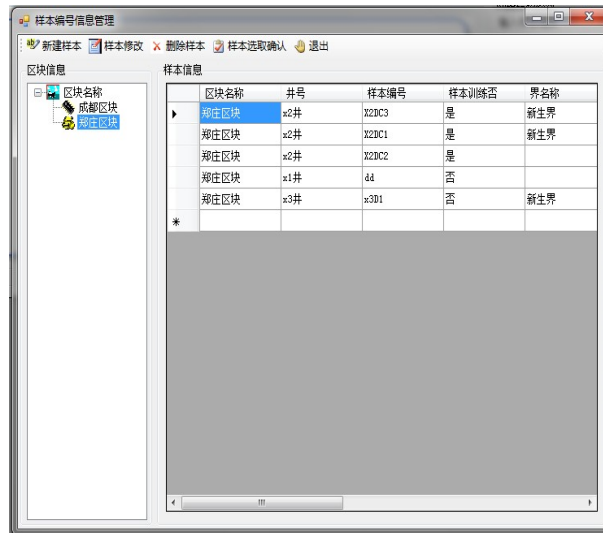


Figure 7. Sample selection interface

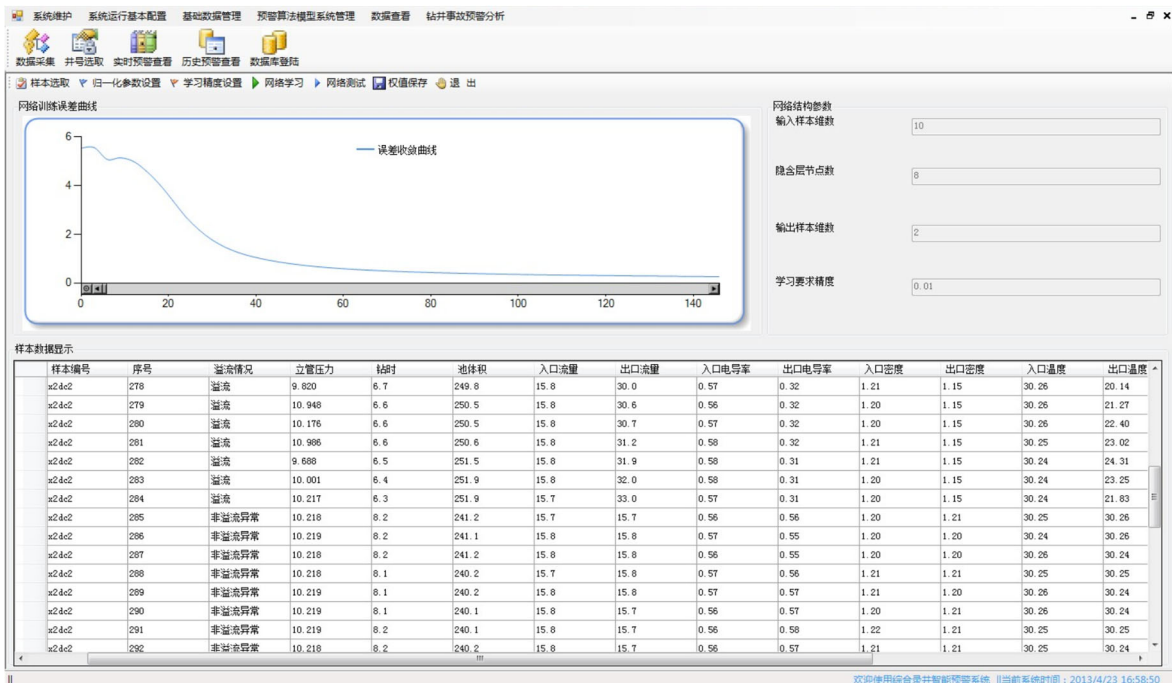


Figure 8. BP neural network training convergence curve interface

## 5. Field Application of Overflow Intelligent Early Warning System in YY Well of XX Oilfield

XX oilfield YY well is a development well, which has overflow situation due to gas intrusion at 2568.6m-2610.1m, meanwhile, the neighbouring well YYS well also has gas intrusion at 2560.7m-2601.2m depth. Therefore, in this paper, the comprehensive logging data of the 2568.6m-2610.1m well section of YY well is selected as the base data, and the data of the 2560.7m-2601.2m well section of YYS well is selected as the sample data, to test the application of the overflow intelligent early warning system based on BP neural network.

Before the system test, the sample data set and test sample

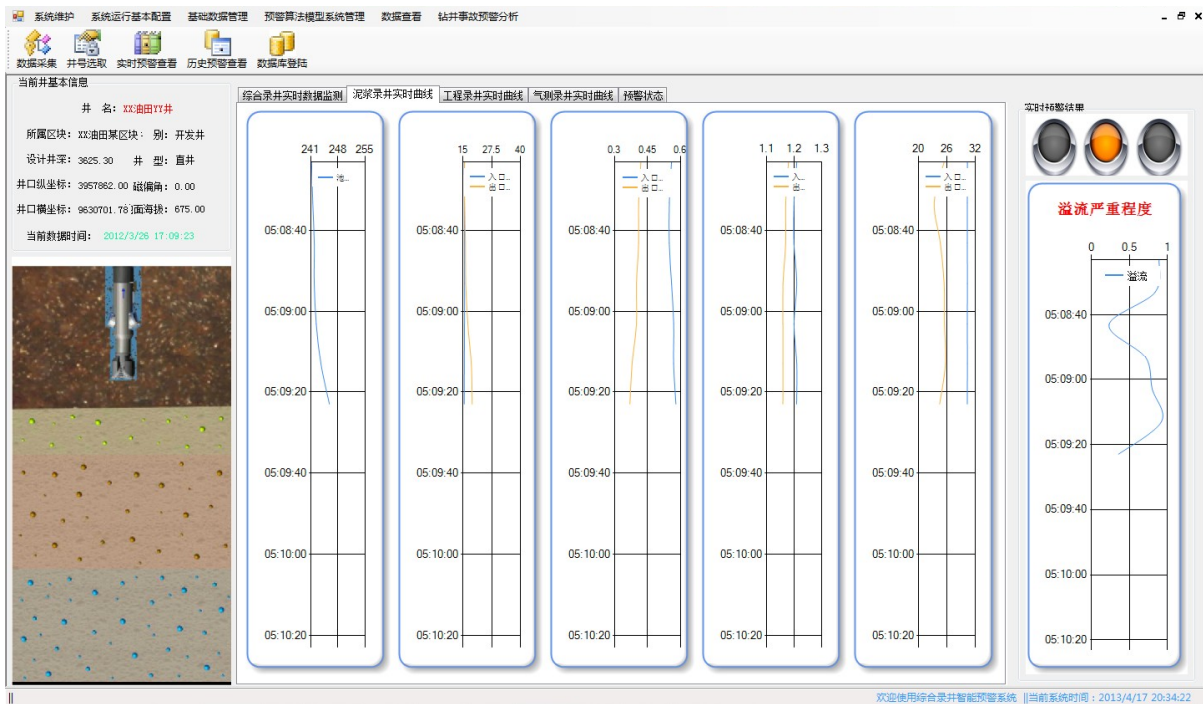
data set were preferably produced by applying the comprehensive logging data of the 2560.7m-2601.2m well section of YYS well, respectively. According to the BP neural network-based overflow intelligent warning model building process described in this paper, the weights and threshold matrices of this well section were obtained, so as to establish the overflow intelligent warning knowledge base applicable to this well section. After establishing the knowledge base, the comprehensive logging data of well section 2568.6m-2610.1m of well YY was input into the overflow intelligent warning model for the calculation of the overflow warning results. The basic data of the comprehensive logging data of well section 2568.6m-2610.1m of well YY and its calculation results, as well as the results of the testing of the overflow intelligent warning software system are shown in Tables 2 and 3 as well as in Figs. 9, 10, and 11, respectively.

**Table 2.** Partial measured composite logging data for well YY

No.	standpipe pressure (MPa)	drilling time (min/m)	pool volume (m <sup>3</sup> )	entrance flow (L/s)	outlet flow (L/s)	inlet conductivity (s/m)	outlet conductivity (s/m)	inlet density (g/cm <sup>3</sup> )
1	9.599	10.2	241.2	15.7	15.8	0.56	0.52	1.21
2	10.253	10.2	241.5	15.8	15.9	0.55	0.51	1.20
.....	.....	.....	.....	.....	.....	.....	.....	.....
10	10.548	9.9	247.8	15.8	16.4	0.56	0.45	1.21
11	11.33	9.9	247.8	15.8	16.4	0.56	0.44	1.20
12	10.264	9.9	248	15.7	16.5	0.56	0.43	1.20
.....	.....	.....	.....	.....	.....	.....	.....	.....
34	10.264	5.7	254.2	15.7	17.1	0.57	0.37	1.20
35	11.33	9.7	254.3	15.8	17.2	0.56	0.35	1.21

**Table 3.** Some measured comprehensive logging data and spillage warning test results for well YY

No.	outlet density (g/cm <sup>3</sup> )	inlet temperature (°C)	outlet temperature (°C)	aeronautics total hydrocarbon (ppm)	C1 (ppm)	BP neural network output	early warning result	reality circumstances
1	1.18	30.26	31.64	36633	23650	(0.8933,0.1377)	overflow	overflow
2	1.17	30.26	32.26	43345	34482	(0.8394,0.0436)	overflow	overflow
.....	.....	.....	.....	.....	.....	.....	.....	.....
10	1.15	30.25	33.28	68557	56683	(0.4293,0.7456)	non-overflow	overflow
11	1.15	30.26	33.26	71726	64683	(0.7005,0.0707)	overflow	overflow
12	1.15	30.26	33.63	76865	67140	(0.7434,0.0831)	overflow	overflow
.....	.....	.....	.....	.....	.....	.....	.....	.....
34	1.14	30.26	35.75	89323	78546	(0.3840,0.6336)	non-overflow	overflow
35	1.14	30.25	35.98	92445	80277	(0.9091,0.0467)	overflow	overflow



**Figure 9.** YY Well Overflow Intelligent Early Warning System Test Results1

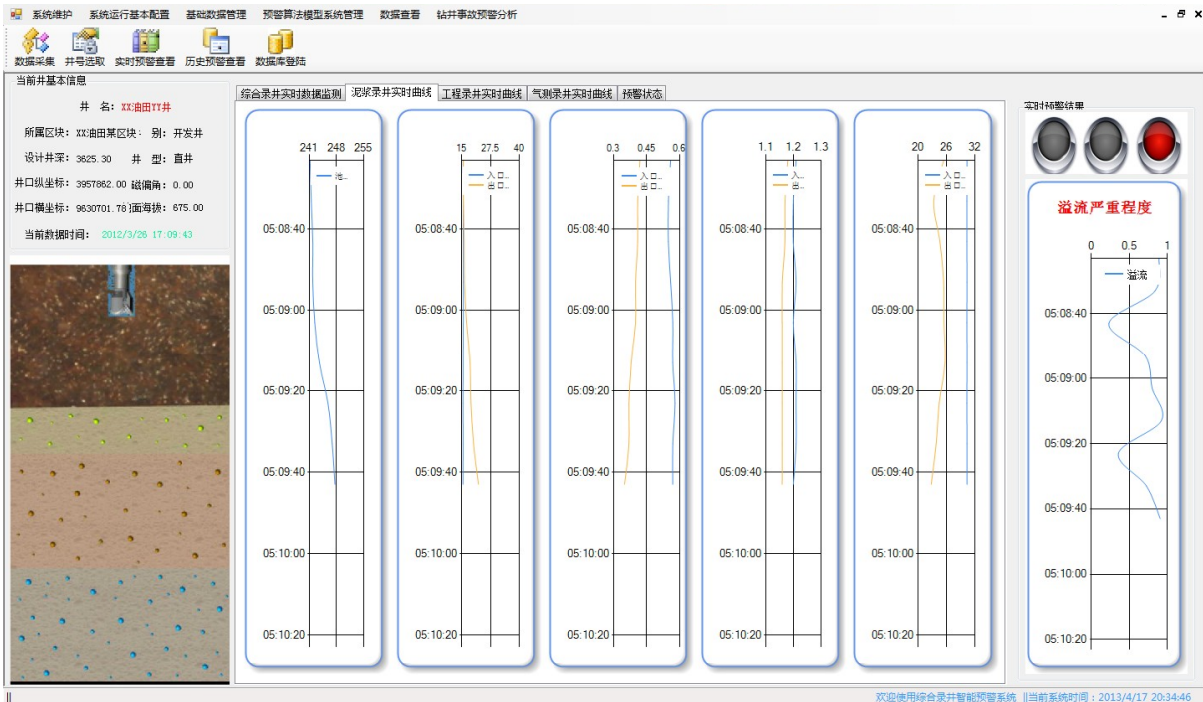


Figure 10. YY Well Overflow Intelligent Early Warning System Test Results2

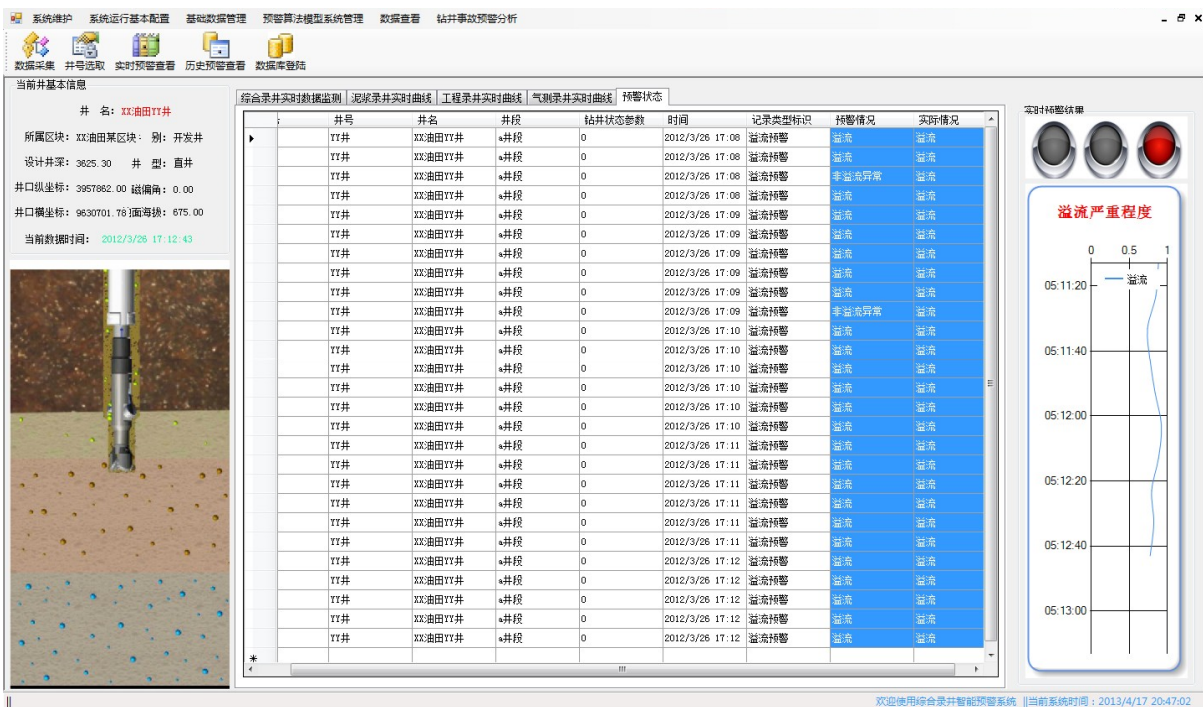


Figure 11. YY Well Overflow Intelligent Early Warning System Test Results3

Table 3 shows that the accuracy of the BP neural network-based overflow intelligent warning system in the 2568.6m-2610.1m section of well YY is 91.43%, which can meet the requirements of field application.

### 6. Conclusions

This paper completes the design and development of overflow intelligent warning module based on BP neural network according to the field application requirements of integrated logging instrument supporting overflow intelligent warning system and the analysis of the establishment process of overflow intelligent warning model. After the application test of integrated logging data of YY wells in XX oilfield, it is shown that the module has good stability and accuracy, and

it is able to provide effective technical support for the on-site overflow warning, and it has good field application prospect.

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