ORGANIZATION OF TECHNICAL-CONDITION MONITORING OF WATER-DEVELOPMENT WORKS AT THE SVETLINSKAYA HPP (VILYUI HPP-3)

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Experience with development and operation of the Svetlinskaya HPP (Vilyui HPP-3) under complex geologic-engineering conditions is unique in both domestic and world practice. Problems associated with development of monitoring-measuring systems for water-development works of the HPP and the shores of the near-dam section of the reservoir are examined. Experience gained with monitoring of the condition of the structures during their construction and in the initial period of service of the HPP is analyzed. It is demonstrated that the hardware/software package employed for the monitoring system, which includes a number of original organizational and technical solutions can also be recommended for application on other projects, primarily those subject to conditions of the Extreme North.

Keywords: Svetlinskaya HPP; water-development works; shore section; monitoring; monitoring-measuring system; hardware/software package.

The Svetlinskaya HPP (Vilyui HPP-3 is the design designation of the Svetlinskaya HPP) was constructed, and is operating under the most complex climatic and geocryologic conditions [1 – 4]. The bed of the water-development works and sides of the Vilyui River Valley are composed of permanently frozen slightly stable semi-rocky soils, which have been disturbed by creep processes, and have an ice content ranging from 10 to 40%. The highly predictable proneness of the soils to slump-type settlement during their thawing after impoundment of the reservoir had predetermined the placement of the concrete on relatively consolidated soils within the bounds of the channel talik. The concrete structures were built from 1987 through 2001, and the left-bank rock-and-earthfill dam (LBRED) from 1992 through 2000. The right-bank rock-and-earthfill dam (RBRED), which intersects the construction canal (placement of fill was begun in 1991) had been completed to the design elevation by the middle of 2008 under the protection of a temporary dike. Both earthen dams are situated on beds comprised of a combination of thawed and frozen sections of various expanses. Since August 2002, the Vilyui River has been passed through bottom spillways of the powerhouse. The three generating sets in the powerhouse had been placed in service in 2004 – 2008 after the reservoir had been filled to the intermediate elevations (Fig. 1). The head on the structure was increased from 12 – 19 m in 2004 – 2005 to 20 – 25 m in 2009 – 2012 with the maximum design head being 31.6 m.

The retaining water-development works were the first in domestic and world practice to be built on semi-rocky permafrost soils. This situation dictated their elevated safety requirements. The need for permanent and active monitoring of the condition of the water-development works and the stability of the shore masses of the head section of the reservoir had been appreciably increased. In this connection, the Siberian Branch of the All-Russian Scientific-Research Institute of Hydraulic Engineering (later the Siberian Scientific-Research Institute of Hydraulic Engineering — SibNIIG, Krasnoyarsk Branch of the JSC "Sibirskii ÉNTTs" had become involved in scientific accompaniment of the construction of the HPP in the initial stage (since 1987). The technical expertise of the No. 13 Survey Expedition of the Lengidroproekt (a component part of the JSC Vilyui HPP-3 since 2000), which currently includes geologic, geodetic, and hydrometeorologic subdivisions, a field observation service, and boring division, has been put to broad use. From the very start, efforts channeled toward field observation and investigations at HPP and their organization have been base on requirements of active regulatory documents. Domestic and foreign experience with similar operations has been defined more precisely. Regular observations have been, and are continuing in all stages of structure performance in the periods of their construction, placement under head, and initial service. In addition to the surveys, the No. 13 Expedition had

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proceeded to perform all observations of the temperature of the bed soil of structures and banks to be constructed, and the levels of ground waters and their salinity, and to built and expand upon their geodetic grid as a basis for design solutions [5].

The Siberian Scientific-Research Institute of Hydraulic Engineering (SSRIHE) has been entrusted with solution of the following problems:

— organization and implementation of regular complex field observations and investigations;

— development of programs for field observations, and a plan and layout for placement of monitoring-measuring equipment (MME) in conjunction with the Lengidroproekt;

— author inspection, procedural and technical supervision of assembly of remote MME, observations based on it, and initial processing of its readings;

— preparatory work on development of an automated diagnostic-monitoring system (ADMS) of the water-development works;

— development and fabrication of secondary equipment for taking of readings of the remote MME on the basis of modern technical solutions and an element base;

— diagnostics of established wire MEE prior to its assembly and placement in long-term service with development of procedures and required instrumentation;

— development of a semi-automated system for interrogation of remote MME and a package of applied software to improve on-going measurements, and processing and analysis of the results;

— monitoring of the status of in-service water-development works; and,

— assignment of safety criteria to water-development works for a declaration of safety for the Svetlinskaya HPP.

The required MME and cable products were purchased by the JSC Vilyui HPP. The MEE was installed during building of the structures by the construction organizations, and the No. 13 Expedition, and later on by the hydraulics workshop of the HPP. The scientific-research field crew (SRFB) of the SSRIHE, which is currently working, was created in 1989 for the purpose of conducting field observations and investigations, improve their effectiveness, and resolve on-going current problems on the construction site of the Vilyui HPP-3 [6].

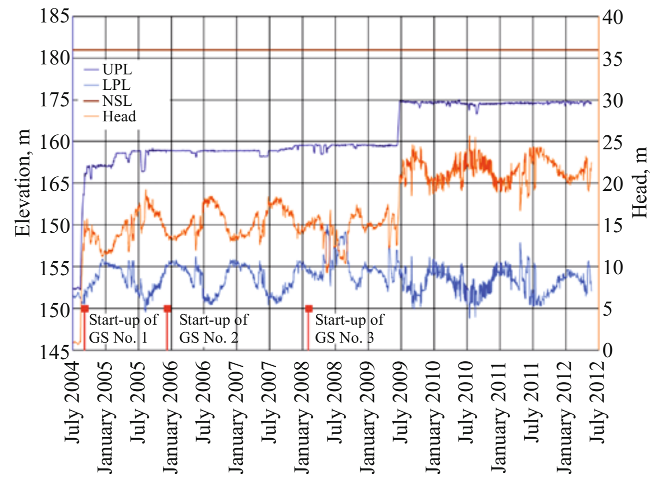

Fig. 1. Levels of upper and lower pools at Svetlinskaya HPP: UPL, upper-pool level; LPL, lower-pool level; NSL; normal support level; GS, generating set.

A system developed for monitoring the status of the water-development works and the shores of the near-dam section of the reservoir, which includes remote, piezometric, and geodetic MEE, observation holes intended for different purposes, and modern hardware components for measurement, transmission, and processing of information with the required applied software, has been developed and is functioning at the Svetlinskaya HPP as a result of the combined efforts of a number of organizations. Information on the

TABLE 1. Information on Remote MEE As Component Part of MMS

Structures and shore zones	Number of measurement transducers, pickups, and observation holes as of March 2012, items									
	PTS, PTR*	PDS	PSAS	PLPS	PLDS*	PS	SG	HP**	DDP	TLH
Concrete										
powerhouse	123	16	79	39	71	41	—	4/20	41	—
retaining walls	5	4	15	4	24	—	—	—	—	—
apron	6	17	19	24	4	—	—	—	—	—
slabs for tailrace stabilization	0	10	3	9	3	—	—	—	—	—
Soils										
LBRED	21	15	—	—	—	16	4	8/426	21	—
RBRED	6	4	—	—	—	39	—	24/1438	47	—
Banks										
left	—	2	—	—	—	8	—	20/861	14	10
right	—	—	—	—	—	—	—	10/449	4	10
Total	161	68	116	76	102	104	4	66/3194	127	20

Notes. 1. WPP, imported wire pressure pickup; SG, strain gage with 3-m base mounted on PLPS-S-160; HP, hot plate in thermometric hole; DP, drop-down piezometer; TOH, thermometric observation hole. * With consideration of MEE installed for construction period. ** Number: in numerator, HP; in denominator, measurement points.

remote and geodetic MME in the structures of the HPP are presented, respectively, in Tables 1 and 2. The monitoring-measuring system encompasses the water-development works and shore section with an area of up to 0.5 × 5.5 km. Work involving refinement and expansion of existing MEE is also continuing at the present time in accordance with a program designed to prepare the structures for elevated upper-pool and normal-upport levels. Systematic visual observations, the composition of which is being adjusted as monitoring tasks change and expand, were conducted during the entire duration of the construction and in the initial in-service period.

Domestically produced wire measurement transducers (WMT), hot plates with digital thermometers, resistive temperature transducers [6 – 8}, and imported wire pressure pickups [9] are used for remote measurement of parameters of the condition of the water-development works at the Svetlinskaya HPP. Unsatisfactory accuracy of the domestic pressure transducers (PDS-3 and 10) dictated the need to convert to transducers manufactured by the Geokon Co. (USA). The drop-down pressure and pressure- free piezometers in the bed of the concrete and earthen structures, and in their shore abutments were fitted with these transducers. As a result of their use, the measurement error of the piezometric levels was reduced from 0.6 and 2 m, respectively, to 3 and 7 cm; this is extremely significant for monitoring of the condition of low-head structures.

The temperature holes in the earthen dams and on the banks are equipped with the hot plates originally designed by the Siberian Scientific-Research Institute of Hydraulic Engineering — Oberon [7]. Considering the extremely complex bed of the structures in geologic-engineering plan, the thermometer spacing was set at 1 m to monitor possible development of filtration through the different interlayers, cracks, etc. Building of hot plates on the basis of series-produced digital thermometers substantially improved the metrological, technical, and in-service characteristics of this measurement unit. Their use for the large volume of temperature measurements at the Svetlinskaya HPP allowed for high accuracy corresponding to standard requirements, and on-going convenience of condition monitoring of the structures. Among other things, monitoring of seasonal temperature variations in the bed of one of the earthen dams permitted over a period of five years timely exposure of a section with a permeability exceeding design requirements as a result of degradation of the grout curtain. Based on results of field observations and control boring, solutions were adopted, and additional grouting work was performed.

The first semi-automatic interrogation system to be used for remote MME (SAIS MME), which includes a special multifunctional type of POVP-01 periodomer [10], remote panel (RP), and software package, has been installed at the Svetlinskaya HPP. The RP are equipped with connectors with soldered-in lead-outs from the measurement transducers and pickups (Fig. 2). One pair of connector contacts is occupied by an automated group-number detector (AGND — a special chip with a punched individual number). Readings are taken by plugging the input cable into the POVP-01 instrument,

TABLE 2. Information on Geodetic MME As Component Parts of MMS

Condition parameter monitored for structures and banks	Measurement hardware	
	name	number, pieces
Powerhouse		
horizontal displacements	plane-elevation mark (PEM)	24
vertical displacements (settlements)	elevation mark, PEM, wall benchmark	111
incline of bed	water level (WL)/elevation mark	4*/177
relative displacements of power-generating units	triaxial slit gages	10
Discharge canal (retaining walls)		
vertical displacements (settlements)	elevation mark, PEM	11
horizontal displacements	plane-elevation mark (PEM)	5
relative displacements of power-generating units	triaxial slit gages	9
Retaining wall of assembly platform		
vertical displacements (settlements)	wall benchmark	8
Rock-and-earthfill dams		
vertical displacements (settlements)	surface mark	60
vertical bed displacements	depth marks (slab mark)	8
Stabilization of left bank		
vertical displacements (settlements)	surface-settlement mark	7
Bank slopes near HPP		
vertical displacements (settlements)	surface mark, geodetic mark	27
Left-bank grout gallery		
vertical displacements (settlements)	surface mark, lateral mark, ground benchmark	31
horizontal displacements	polygonal point	6
Edge of reservoir		
vertical displacements (settlements)	surface mark, geodetic mark	61

* Individual WL are tied one to another with respect to elevation by geodetic leveling.

which is equipped with a connector-response section. The number of the group and the readings of the pickups, which are entered to the instrument's memory, are read during the measurements. The official applied software for the instrument provides for transfer of the remote-MME readings from the memory of the POVP-01 to a personal computer (PC). A special program in the PC executes automated address deliver of the measurements for each pickup with use of conversion tables from processing files ("Excel" format). For the wire transducers, this is the period of the wire oscillations, and the electrical resistance of the coil, and for resistance transducers, it is their resistance. A segment of the conversion table is presented in Table 3 as an example. Initial processing of the transducer readings, which are brought to measurable physical quantities (temperature, pressure, relative strain, displacement, force, etc.), is carried out in processing files.

Connectors from hot plates established in holes in the earthen structures and banks are placed on these same RP. Taking of the hot-plate readings, their storage, and transfer to the PC are executed with use of an information-transfer unit (ITU) [7]. The high efficiency of the SAIS employed, which makes it possible to reduce labor outlays and shorten (by up to three-five times) the time required for assembly and processing of data from embedded MME, is confirmed by practice.

Depending on the location of the remote MME, its readings are taken with a frequency of from one to 2 – 3 times per week. The condition of the earthen dams and the bed of the powerhouse is monitored most frequently. When necessary (passage of high water, rise in the upper-pool level, etc.), observations of a particularly significant group of MEE are performed daily.

The field-observation service (FOS) includes supervisors and three coworkers. Its staff has not changed over a period of seven years, despite a significant increase in the number of remote MME during this period. Creation and development of the SAIS for MME, and the high level to which measurement hardware and applied software have been installed

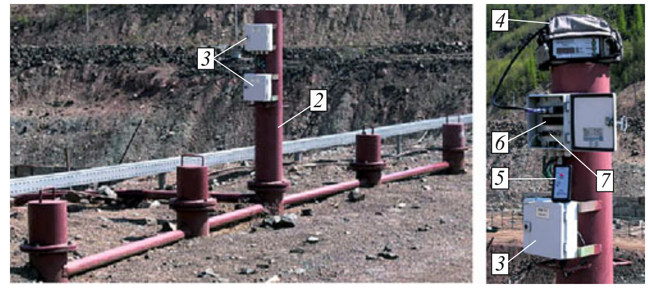

Fig. 2. Example of situation at heads of holes with remote MME on earthfill dam: *a*, measurement site (piezometers and hot plates); *b*, external panels and measuring instruments; *1*, piezometers; *2*, thermometric hole; *3*, RP; *4*, POVP-01; *5*, ITU; *6*, connector from pressure transducers to lead-outs; *7*, thermobelt connector.

have made it possible for personnel of the FOS without adding to their number to conduct a constantly increasing volume of work. At the present time, up to 500,000 – 550,000 measurements are taken annually by remote MEE. Results of the observations are processed rapidly, and are analyzed in an on-going regime.

One of the basic and mandatory requirements established for the monitoring system installed for water-development works is assurance of high information reliability. The wire-type of measurement transducers are usually the base of the telemetric-monitoring systems employed for water-development works. After installation in the body of a structure, they are inaccessible for repair and replacement, and the periodic checks required to determine their metrological characteristics. By virtue of this, the set of output-signal parameters from the combination of which a conclusion is drawn concerning the condition of the transducers and the reliability of the information obtained from them is the only tool available for MME evaluation. The data base and bank of the transducers are also used for the analysis.

As a component part of the remote MME, wire measurement transducers have been installed in the water-development works during the in-service period of the Svetlinskaya

TABLE 3. Segment of File-Based Submission of Transducer Readings in Concrete Structures

Group number	Number in group	Path to file for processing of transducer readings and data storage	Name of file	Transducer		Observations		Readings			
				No.	type	date	time	t, μsec	dT, %	R, Ω	dR, %
001	01	C:\MME\Concrete\Apron\	P3-1-04	PE0084	PDS 10	B*	C	D	E	I	J
001	02	C:\MME\Concrete\Apron\	P3-2-12b	TE4816	PTR	Z	AA			AB	AC
001	03	C:\MME\Concrete\Apron\	P3-2-12b	TE4846	PTR	H	I			J	K
001	04	C:\MME\Concrete\Apron\	P3-2-12b	TE4879	PTR	N	O			P	Q
001	05	C:\MME\Concrete\Apron\	P3-2-12b	TE6658	PTR	T	U			V	W
001	06	C:\MME\Concrete\Apron\	P3-2-12b	TE4902	PTR	B	C			D	E
001	07	C:\MME\Concrete\DownApron\	P4-2-13	LE0043	PLPS 10	U	V	W	X	AB	AC
001	08	C:\MME\Concrete\DownApron\	P4-2-13	LE2700	PLPS 10	L	M	N	O	S	T
001	09	C:\MME\Concrete\DownApron\	P4-2-13	CE0265	PSAS 28	B	C	D	E	J	K

Notes. 1. T and dT are, respectively, the period of the wire oscillations and its measurement error. 2. R and dR are, respectively, the resistance of the resistive or wire-coil transducers and their measurement error. * The Latin letters denote the columns of the processing file to which the corresponding data is entered.

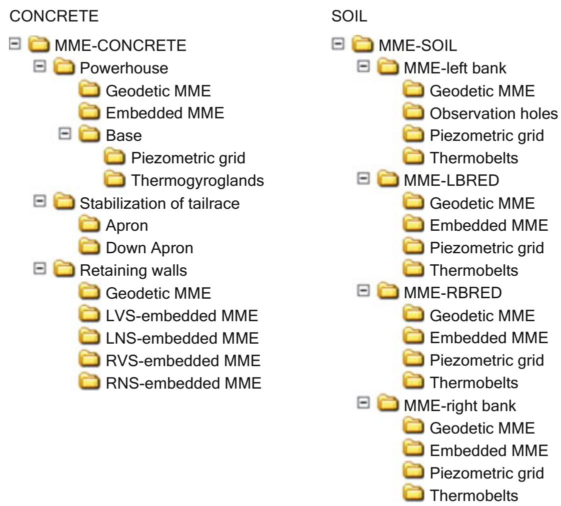

Fig. 3. Catalogued structure of location of MME field data in personal computer.

HPP, starting in 1989. More than 80% of these transducers have continued to function to the present. The first monitoring points in the concrete structures are being fitted 15 years after the start of the reservoir's impoundment for start-up of the first hydraulic generating set of the HPP. Operating experience indicates that for a number of reasons, these wire transducers may eventually yield information with a significant error, having maintained their long-term serviceability here (20 – 30 years and longer). A diagnostics procedure, which enables us to expose disturbances in the metrological characteristics of the WMT, is used to ensure unconditional reliability of information obtained from the embedded wire MME. This problem is solved by periodic (with an interval of one-two years) complex inspections of output-signal parameters of the WMT, which can be performed with use of the original instrument and subsequent processing of results by a special procedure. Regular diagnostics make it possible to substantiate the reliability of the readings taken from the embedded wire MME, and continue its use in the system for monitoring the condition of the water-development works at the Svetlinskaya HPP. In this connection, the CTO requirement [11] concerning rejection of readings of embedded wire transducers for application only on the basis of progressive symptoms with no evaluation of the reliability of their readings is erroneous, especially for lengthy construction times.

The electronic archive (bank) of MME-observation data on the condition of the water-development works at the Svetlinskaya HPP is compiled on the basis of electronic "Excel" tables. In addition to accumulation of measurements from remote MME, initial processing with respect to calibration relationships and algorithms is performed in these tables. +ure 3 shows the catalogued structure of the location of field data from MME in the concrete and earthen structures at the Svetlinskaya HPP on the magnetic disk of the PC. The files of electronic Table are grouped into individual portfolios, proceeding from the position of the transducers in isolated structural components of the concrete and earthen structures of the hydroproject, and, in part, from their purpose. The names of the portfolios presented in Fig. 3 are denoted as follows. MME-CONCRETE and MME-SOIL — root portfolios, which contain the entire MME data base, applying, respectively, to the concrete and soil structures, their beds and the banks of the near-dam portion of the reservoir. The root portfolios include intermediate portfolios, (for example, MME-LBRED, in which portfolios of MME of different purposes (for example, the "piezometric grid" with readings of remote MME in the piezometers) are located in turn. The basic part of the data from MME embedded in the concrete structures of the hydroproject, with the exception of the piezometric grid, is grouped in files, the names of which correspond to the specification of the blocks concreted during construction. The numbers of the transducers are codified in the archive. The first symbol denotes the type of transducer, and the second corresponds to the type of monitoring (constriction or in-service). The last four symbols represent the transducer number corresponding to the numbering system devised by the person preparing the file. The unified system adopted for the numbers of the transducers also permits rather rapid sorting and search of the electronic tables for transducers based on type. The structure of the initial processing of measurements from the embedded MME in the electronic tables is determined by the calibration relationships, type of transducer, and also the form of the physical parameter being monitored. The processing algorithms are visibly recorded directly in the cells of the electronic tables.

For each period and electrical-resistance measurement, the random error (RE) is automatically calculated by the POVP-01 instrument, and is enter in special columns of the files. Transducer readings with an RE of 0.3 – 1% and greater are automatically marked with different colors to warn the user about the quality of MME information and the expediency of its use for evaluation of the in-service reliability and safety of the water-development works.

Permanent information on the transducers installed in the structures, which includes their serial number, date of manufacture and installation, location coordinates, individual calibrations, formulas for conversion to parameters, initial reading, etc. is entered to the MME data base.

Results of observations based on the geodetic MME and holes, measurements in which are taken by portable hardware (upper and lower pool levels, and water and air temperatures), are manually entered to the electronic archive.

The diagnostic condition indicators of the structures with their criterial values are compared in a special file after each cycle of measurements taken from the embedded and geodetic MME. The MME readings are submitted in reduced form to the user as tables and graphs.

Use of the electronic "Excel" tables for management of the electronic base (bank) of field observations permits ongoing alteration of the structure, and initial processing and analysis (analytical and graphical) of field information as applies to current tasks associated with monitoring of the con-

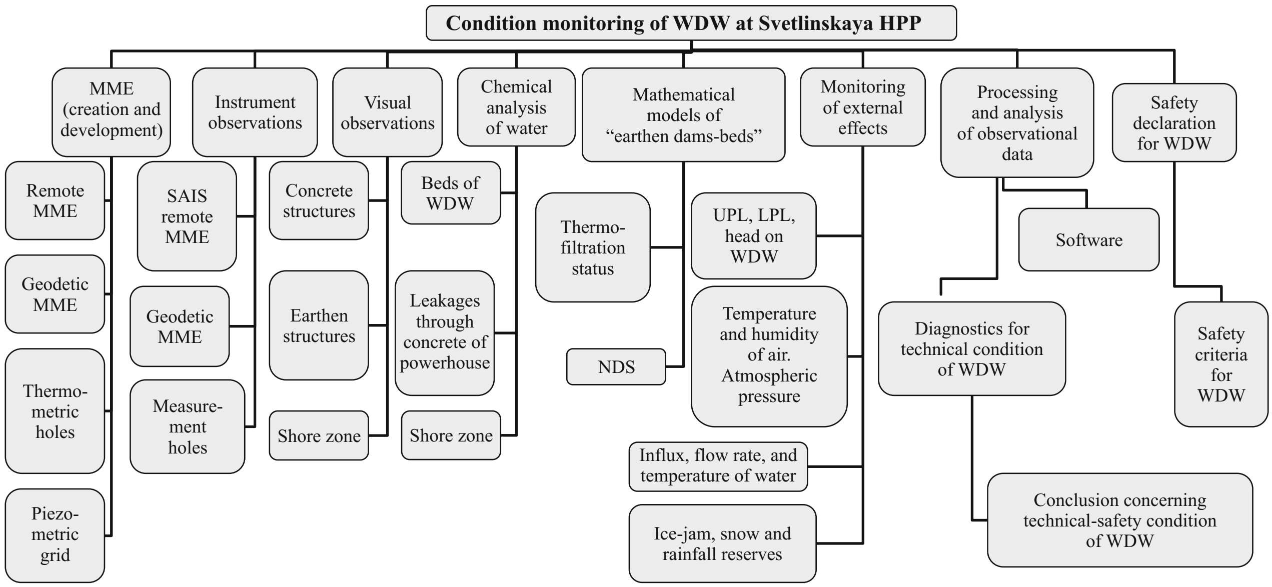

Fig. 4. Process-flow diagram of monitoring of water-development works (WDW) at Svetlinskaya HPP: UPL, upper-pool level; LPL, lower-pool level; head on WDW.

dition of the water-development works. Proceeding from the open architecture of "Excel," moreover, such variation is completely accessible to engineering and technical personnel of the field-observation service at the HPP.

Figure 4 shows the process-flow diagram of the monitoring of the water-development works at the Svetlinskaya HPP. The condition of the water-development works and the stability of the banks of the near-dam section of the reservoir are evaluated on the basis of complex analysis of the results of all types of filed observations and the readings of all MME (remote, piezometric, geodetic). Here, coordination of the activity of those participating in the field observation, primarily in the periodicity and form in which the results are presented, assumes major significance. The in-service reliability and safety of the water-development works at the Svetlinskaya HPP are systematically analyzed and evaluated by the JSC Lengidroproekt and the Siberian Scientific-Research Institute of Hydraulic Engineering, Krasnoyarsk Branch of the JSC "Sibirskii ÉNTTs". As a result of the situation that has been unfolding historically, a number of organizations and subdivisions are conducting the field observations (Table 4). In addition to the data that are output on a regular basis to those participating in the monitoring, all types of information referring to the field observations and status of the structures are accessible in in real time when needed. The hydrotechnical workshop (HW) at the Svetlinskaya HPP visually monitors the condition of the concrete and earthen structures and their individual components, assembles and performs technical maintenance on the remote MME placed in service, and analyzes observations submitted by other organizations in their current work. Readings of the remote MME are taken by the field-observation service, which performs its work under the technical guidance of the SRFB of the SSRIHE. With respect to the geodetic MME, the observations are made by Expedition No. 13, and the JSC Lengidroproekt participates in analysis of the data obtained. The Division of Geology continues to observe the thermometric and piezometric holes, the equipping of which by stationary remote MME has yet to be completed, and is involved with analysis of the condition of the earthen dams and banks.

Observations of vertical and horizontal displacements of the concrete and earthen water-development works, left-bank grouting galleries, slopes in the area of the HPP, and the shores of the reservoir with respect to previously placed monitoring stations are carried out by geodetic methods. Special geodetic grids linked one to the other were created during the construction period, and are also being used in the in-service period. Plane and elevation grids in the section of the basic structures are intended for observation of deformations of the structures, their beds, and the surrounding area. The plane and elevation grids of the near-dam section of the reservoir (with an expanse of more than 5 km from the site of the hydroproject) are intended for study of slide processes and reformation of the banks.

External loads and effects are monitored. The powerhouse is fitted with remote equipment for measurement of the water levels in the upper and lower pools. The hydrometeorologic service conducts regular station observations of the levels, influx from tributaries, flow rates, and temperature of the water, atmospheric pressure, and the temperature and humidity of the ambient air. The seasonal temperature variation of the water in the reservoir (Table 5), including the near-bottom layers, makes it possible on the basis of temperature observations of the water-development works to evaluate the thermal filtration condition of their beds and the cores of the dams, and the effectiveness of the anti-filtration devices.

Cryopegs with a salt content ranging from 10 to 80 g/liter, which are gradually displaced by the water of the reservoir, reside beneath the stratum of permanently frozen rocks. The chemical laboratory at the Svetlinskaya HPP regularly monitors the variation in the mineralization of groundwater by extracting water samples from the piezometric grid. These data, together with results of other observations, are used to evaluate the filtration status of the beds of the structures and shore masses.

The entire volume of information obtained from these observations is submitted to the SRFB of the SibNIIG, which on the basis of this information:

— performs on-going monitoring with rapid analysis of the condition of the in-service water-development works, which is based on the safety criteria developed;

— draws quarterly conclusions with an evaluation of the status of the water-development works; and

— issues technical information biannually on the basis of observational results from all types of MME.

Moreover, the SibNIIG publishes conclusions concerning the condition of the earthen dams (annually), and once every two years. Using the geologic materials and data derived from field observations, the SibNIIG also develops computational models of the thermo-filtration and stress-strain states of all earthen dams and the left-bank abutment.

The combination of studies performed and technical interaction among those participating in the monitoring ensures current control of the status of the water-development works at the Svetlinskaya HPP at the required level and with timely adoption of adequate measures with respect to their in-service safety. During the construction and initial in-service periods of the structures, for example, the components of the anti-filtration devices in their beds, have therefore undergone substantial changes based on results of the monitoring of their condition. The single-tier grout curtain in the bed of the powerhouse has been strengthened, and replaced by a three-tier curtain during repeated grouting in 2008. An ineffective two-tier grout curtain was rejected for the beds of both earthen dams, and replaced by a more reliable anti-filtration installation — by an in-ground pile wall formed

TABLE 4. Participants in Monitoring and Their Exchange of Observational Data on Regular Basis

Participant	Data presented		Information user			
	type	periodicity	Vilyui HPP-3	Svetlinskaya HPP	Lengidro-proekt	SibNIIG (NIPO)
Expedition No. 13	Readings of remote MME	Daily	–	–	–	+
	Results of geodetic observations	Quarterly	+	+	+	+
	Results of hole observations	Monthly	+	–	+	+
	Hydrometeorologic information	Monthly	+	+	+	+
Svetlinskaya HPP	Results of visual monitoring	Quarterly	+	+	–	+
	Pool levels, information on operation of generating sets and spillways, flow rates of water	In real time	+	+	–	–
	Results of chemical analysis of water samples	Monthly	+	+	–	+
SibNIIG	Conclusions concerning status of water-development works from results of rapid analysis of their condition	Quarterly	+	+	–	+
	Technical information on observations based on all types of MME	Once in six moths	+	+	+	+
	Conclusions on condition of earthen dams	Annually	+	+	–	+
	Conclusive technical reports on monitoring results	Once in two years	+	+	–	+
	Evaluation of condition of "earthen-dam/bed" system. Mathematical models	As required	+	+	–	+
Lengidro-proekt	Reports on studies and observations a) geodetic-engineering b) hydrometeorologic c) geologic-engineering	Quarterly and annually	+	+	+	–

TABLE 5. Water Temperature Throughout Depth of Reservoir of Svetlinskaya HPP in 2010 – 2011

Depth, m	Temperature of water at mid-month through years, °C											
	V		VI		VII		VIII		IX		X	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
5	4.7	5.2	7.4	6.0	14.5	15.4	13.6	13.1	9.9	9.2	3.7	6.0
10 – 28	4.7	5.2	7.4	5.9	12.7 – 11.0	10.1 – 8.3	13.5 – 13.2	9.5 – 8.5	9.9	9.2	3.7	6.0

from clay-cement concrete with a left-bank frost curtain. The quantitative and qualitative field information gathered on the project is also used for development of criterial values of diagnostic condition parameters of the water-development works within the framework of their safety declaration.

CONCLUSIONS

1. The developmental and in-service experience gained with the Svetlinskaya HPP under the most complex geologic-engineering conditions is unique in both domestic and world practice. Moreover, the significance of continuous and effective monitoring of the condition of the water-development works and banks of the near-dam section of the reservoir has been substantially elevated. A developed monitoring-measuring system encompassing a zone of up to 0.5×5.5 km has been created for this monitoring.

2. The plans implemented for placement of the MME, and the program of observations are developed with consideration of the existence of the freezing-thawing beds of the water-development works and the permafrost soils in the shore section of the reservoir. Studies to improve and expand upon the existing monitoring-measuring system will continue hereinafter based on a program devised to prepare the structures for a rise in the upper-pool and normal-support levels.

3. The monitoring-measuring complex of the monitoring system, which has been created and is evolving at the HPP, includes a number of new organizational solutions ensuring the required accuracy and reliability of monitoring, high operational effectiveness of the measurements, and processing and analysis of the results. A semi-automated system for interrogation of remote MEE, which eliminates the effect of the human factor on the results of field observations and at the same time reduce the labor outlays for these observations, is an original component of this complex. Regular diagnosis of embedded wire MME allows for evaluation of the reliability of its readings, extends its service life beyond the average value, and rejects transducers with questionable metrological characteristics in a timely manner.

4. The expediency and high effectiveness of the organization of permanent representatives of scientific-research institutes of the appropriate profile (field crews, or expeditions for large-scale projects, which include highly qualified specialists) at domestic water-development works for successful solution of problems encountered in scientific accompaniment during their construction and service, and monitoring of their technical condition are substantiated.

5. Multiyear experience with the organization and execution of control observations at the Svetlinskaya HPP can also be successfully employed on other projects, primarily for their design, construction, and service under conditions of the Extreme North.

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