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Hydrogeological conditions of Irpin and their influence on the city's engineering protection and construction assessment

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The scheme of engineering-construction assessment, which is created based on engineering geological zoning of the city's territory is desirable among additional graphic materials in the design of master plans projects as determined by state building norms [State…, 2012]. Engineering geological zoning provides for different ranks' selection of taxonomic engineering-geological units, which have a particular range of common engineering geological conditions that ultimately determine the construction sites' affiliation to a specific suitability category. Geological-lithological structure and hydrogeological conditions of the Irpin city, Kyiv region are investigated, and the types and degrees ofgroundwater aggressiveness, chemical composition, and mineralization of groundwater, the depths of the first aquifers from the day surface are highlighted in this article. A variant of the creation of large-scale maps of groundwater depth and chemistry based on a hydrogeological survey conducting is presented. The analysis of hydrogeological circumstances of the city's territory lays the foundations for the selection of engineering-geological sites based on the comparison of this information with geomorphological, engineering-geological and geodynamic data. Complexity assessment of hydrogeological conditions and accounting of hydrogeological factors for the construction assessment scheme and selection of corresponding measures of engineering training and protection of the problem construction sites has become an ultimate result.

Key words: hydrogeological conditions, geological-lithological structure, hydrogeological maps, engineering protection, construction assessment.

Introduction. Today Irpin is one of the most dynamically developing cities with a fairly dense built-up area, which is located within the boundaries of Kyivsky Polesia, which is characterized by excessive humidity, as well as complex hydrogeological construction conditions. Hydrogeological studies and observations within the city of Irpin are designed to contribute to a comprehensive assessment of hydrogeological conditions in construction, the study of the nature and degree of influence of various hydrogeological factors on the conditions of construction and operation of engineering structures. An assessment was made of the possible impact of the designed structures on changes in the hydrogeological conditions of adjacent territories, the aggressive and corrosive effects of groundwater on the underground parts of engineering structures and their possible impact on the development of geohazards. A system of measures has been developed to ensure more favorable conditions for construction in the existing hydrogeological conditions. [Slynko, 1992].

The main purpose of this article is the description of the hydrogeological structure of Irpin's city and the identification of aggressive and corrosive properties of groundwater concerning concrete and metal parts of structures, the location of groundwater levels, the chemical composition of groundwater and its mineralization. Ultimately, the collected hydrogeological data for Irpin city made it possible to select technical solutions and justifications for the construction and organization of protective measures.

Geological-lithological structure. Let us first outline the geological-lithological structure of the city before proceeding to the description of Irpin's hydrogeological conditions.

Irpin is situated on the borders of the Ukrainian Shield's northern-east slope in geostructural terms, which gradually dips in a north-easterly direction to the side of the Dnieper-Donets Rift. The sediments of the Cretaceous, Paleogene and Quaternary systems lie on the eroded surface of the Precambrian basement. Deposits of the Cenomanian layer, represented by sands and sandstones on siliceous cement are the oldest sedimentary formations exposed in the territory of Irpin. The sand is greenish-gray, fine- and medium-grained, quartz-glauconite. Deposits of the Upper Cretaceous are on the rocks of the Cenomanian layer represented by white, light gray chalk with an average thickness of 9.0 m. The Kaniv, Bucha, Kyiv and Kharkiv suites are established as part of the Paleogene sediments. Rocks of the Kaniv Formation (P_2kn) lie on chalk rocks and are represented by shallow marine formations: dark gray fine- and fine-grained glauconite-quartz, micaceous sand with underlying layers of aleurites and clays, and sometimes sandstones. The thickness of the Kaniv suite varies from 20.4 to 30.5 m with an average thickness of 25 m [Ivanenko, 2020].

The sediments of the Bucha suite (P_2bc) lie on the Kaniv sediments and are overlain by clays and marls of the Kyiv suite, they are represented by shallow marine formations: greenish-gray, fine- and fine-grained sands of quartz-glauconite composition and dark green and greenish-gray clays with thickness from 8.0 to 20.0 m.

Deposits of the Kyiv suite (P_2kv) are represented by a layer of greenish-gray clayey marls, which pass into marly clays with a thickness of 4.0—30.0 m. A significant change in the capacities of the Kyiv suite is due to its erosion in the Irpin and Buchanka Rivers' riverine zones for which the Kyiv suite's deposits are a water-resistant layer. Deposits of the Kharkiv suites (P_3ch) are limitedly distributed on the territory of the city's south-western part, where they are confined to the most mountainous part of the watershed between the Irpin and Buchanka rivers, they are blurred in the rest of the area in Quaternary time. The sediments of the Kharkiv suite are gray, greenish-gray, shallow- and fine-grained sands of quartz-glauconite composition with a thickness of 4.5—5.0 m [Solovytsky, Vozgryn, 1990; Tsybko, 2020].

Quaternary sediments completely cover pre-Quaternary formations. They are represented by the following genetic types: water-glacial, glacial, alluvial, marsh and technogenic. Quaternary deposits in terms of age are represented by Middle Quaternary, Upper Quaternary and modern sediments.

Mid-Quaternary water-glacial submarine sediments (Q_{II}fdn1) lie on formations of the Kharkiv and Kyiv suites. They are widely distributed on the city's territory and make up the highlands between the Irpin and Buchanka Rivers. They are represented by yellow-gray, gray, ochreous, fine- and medium-grained, quartz sands with admixtures of feldspars with layers and lenses of clays. They overlap with moraine and water-glacial moraine sands with a capacity of up to 12 m [Panchenko, 2019; Tsybko, 2020].

Mid-Quaternary glacial (moraine) deposits (Q_{II}gdn$_2$) are represented by glacial deposits with red-brown loams and clays, sometimes greenish-gray with ocher spots of ferrugination with inclusions of gravel and pebbles of crystalline rocks. Coarse-grained material is represented by granites, gneisses, limestones and sandstones. Moraine sediments were not widely distributed, they were preserved only in upland watershed areas and remnant mounds. The moraine deposits are covered everywhere by fluvioglacial deposits, their thickness ranges from 3.0 to 11.5 m.

Mid-Quaternary water-glacial over-moraine deposits (Q_{II}fdn$_3$) are the most widely distributed on the city's territory, they are the basis for the foundations of most buildings and structures. They are represented by light-gray, brown-yellow and yellow-gray quartz sands. Sands are multi-grained, medium-grained prevail. Sandstone layers and lenses are often found in gravel-pebble material with a thickness of 0.2—2.7 m, including boulders of crystalline rocks. The total thickness of fluvioglacial deposits varies from 5 to 20 m with an average thickness of 10 m.

Alluvial Upper Quaternary $Q_{III}al$ deposits are represented by alluvial formations of the Irpin and Buchanka Rivers' floodplain terraces — quartz, fine-grained, light-gray and yellow-gray sands with a thickness of 8—12 m with interlayers and lenses of sands with a thickness of 0.2—0.5 m. Alluvial deposits lie on the washed-out surface of Kyiv suite's marls.

Modern Quaternary alluvial $Q_{IV}al$ and biogenic $Q_{IV}b$ deposits consist of the floodplain of the Irpin and Buchanka Rivers. They are represented by fine-grained light-yellow and gray-yellow quartz sands with a thickness of 10—16 m with lenses and interlayers of sandy loams and silts with a thickness of 0.13—0.9 m. Biogenic deposits are represented by peat with a thickness of 0.3—5.0 m, which covers alluvial deposits in most of the floodplain. Peat is mainly poorly decomposed, brown and brownish-brown in color. The composition of peat is dominated by reed material. Peat is often sandy, which is the result of washing out the organic component from its mass (Fig. 1—3) [Alekseev, 1980; Tsybko, 2020].

Hydrogeological conditions. Five aquifer complexes are distinguished within the Irpin city's territory by the geological structure and geostructural features of the district:

– aquifer complex confined to Modern and Upper Quaternary alluvial deposits;

– an aquifer complex confined to Mid-Quaternary water-glacial and glacial deposits;

– aquifer complex in Bucha-Kaniv sediments;

– aquifer complex in Cenomanian sediments;

– aquifer complex of the fractured zone of Precambrian crystalline rocks [Kostyuchenko, Shabatyn, 2005].

The aquifer complex confined to Modern and Upper Quaternary alluvial deposits (a_{III}—a_{IV}) represents an aquifer that is tied to floodplain deposits and areas of the first supraflood terraces of the Irpin and Buchanka Rivers. The capacity of this aquifer does not exceed 10—12 m. The aquifer water rocks are fine, medium and coarse sands with interlayers and lenses of sandy loams and loams.

The depth of the groundwater table depends on the topography and constantly increases from the riverbeds toward the original shore. The maximum level marks for the period of the spring flood in 2020 were: within the floodplain 109—112 m, on the first supraflood terrace 113—115 m. The Kyiv suite's marl serves as a water barrier for this horizon.

The surface of the Kyiv marls exceeds the absolute marks of their surface within the valley by 3—8 m within the watershed, due to which the waters of the Mid-Quaternary aquifer complex drain over the surface of this aquifer into the valley. This aquifer is used by the local population for domestic water supply with the help of mine wells due to the shallowness of the groundwater table. Flow rates of wells are 0.01—0.07 l/s with a drop of 0.5—1.0 m.

The aquifer is fed by the infiltration of atmospheric precipitation, flood waters and flow from the Mid-Quaternary aquifer complex from the side of the original bank.

The waters' chemical composition of the Buchanka River valley is mainly calcium-magnesium-sodium sulfate, while the Irpin River valley's waters are calcium-magnesium-sodium bicarbonate. The waters are fresh with mineralization up to 1 g/l. The pH value varies from 4.9 to 6.1, and the total hardness from 2.2 to 14.1 mg/eq. Water has weak general acid aggressiveness towards concrete (II types of corrosion) [Tsybko, 2020].

The aquifer complex confined to the Middle Quaternary water-glacial and glacial deposits (f, $g_{II}dn$) is widely developed on the city's territory within the watershed between the Irpin and Buchanka Rivers. Aquifer rocks are heterogeneous in lithological composition and are represented by sands, sandy loams, loams and clays with the inclusion of pebbles and boulders. This complex represents a single hydraulically connected system and is therefore considered a single aquifer complex, taking into account that the moraine deposits on most of the city's territory are eroded and preserved in the form of outcrops. The Kyiv suite's marl serves as a water barrier. The depth of the groundwater table varies widely

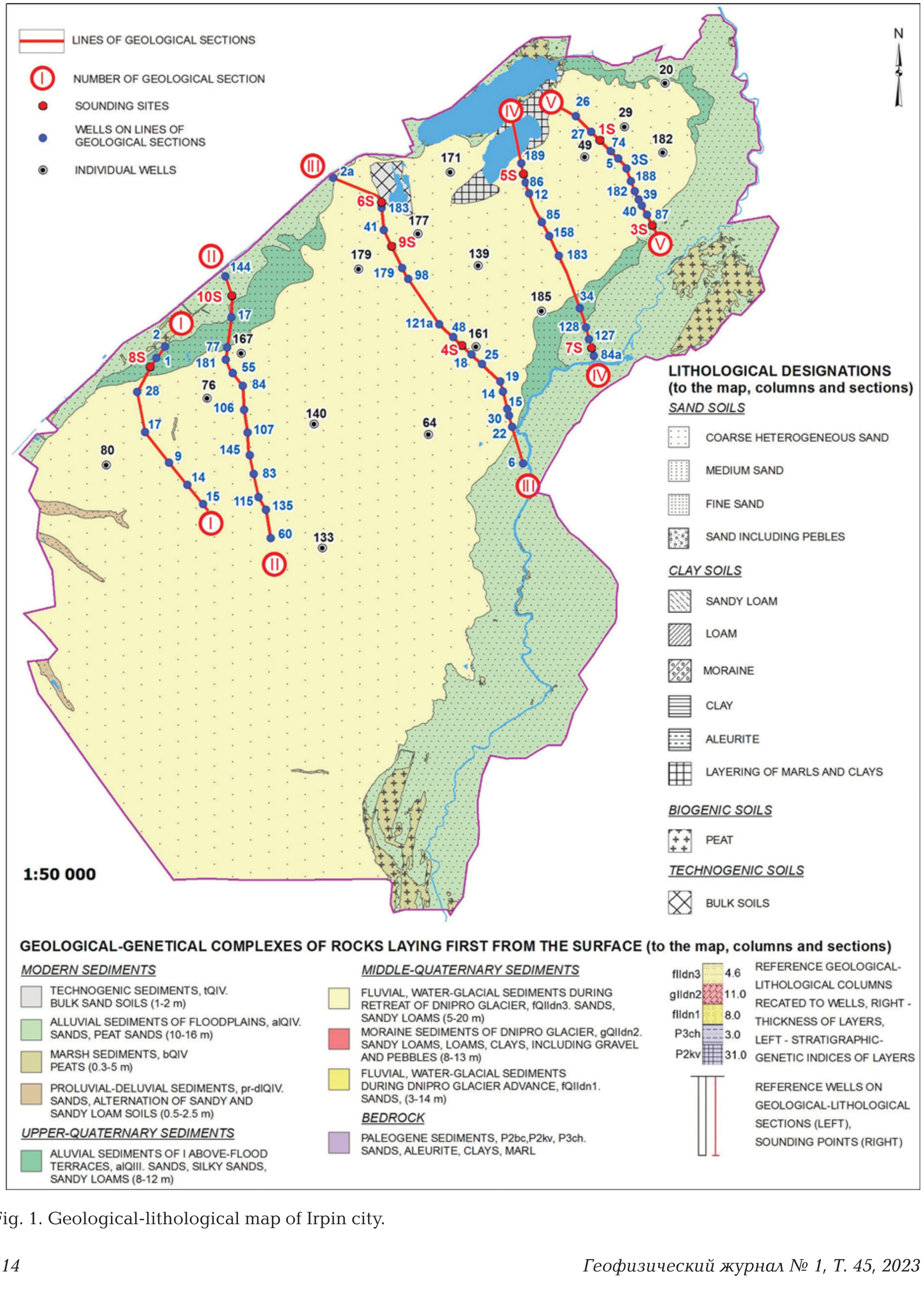

Fig. 1. Geological-lithological map of Irpin city.

from 0.5 to 25 m increasing towards the elevated part of the watershed.

The aquifer complex is fed by the infiltration of atmospheric precipitation. It is drained by the river valleys of Irpin and Buchanka. The amplitude of level fluctuations is 0.5—0.8 m. The maximum levels are observed in the spring period and the minimum levels are observed in the summer.

The chemical composition of water is sulfate-hydrocarbonate calcium-sodium-magnesium and sulfate-chloride calcium-sodium. Increases in sulfates, nitrates, and chlorides are associated with surface pollution. The waters are fresh and slightly mineralized (up to 2.6 g/l) according to the mineralization's degree.

Water confined to the more elevated ar-

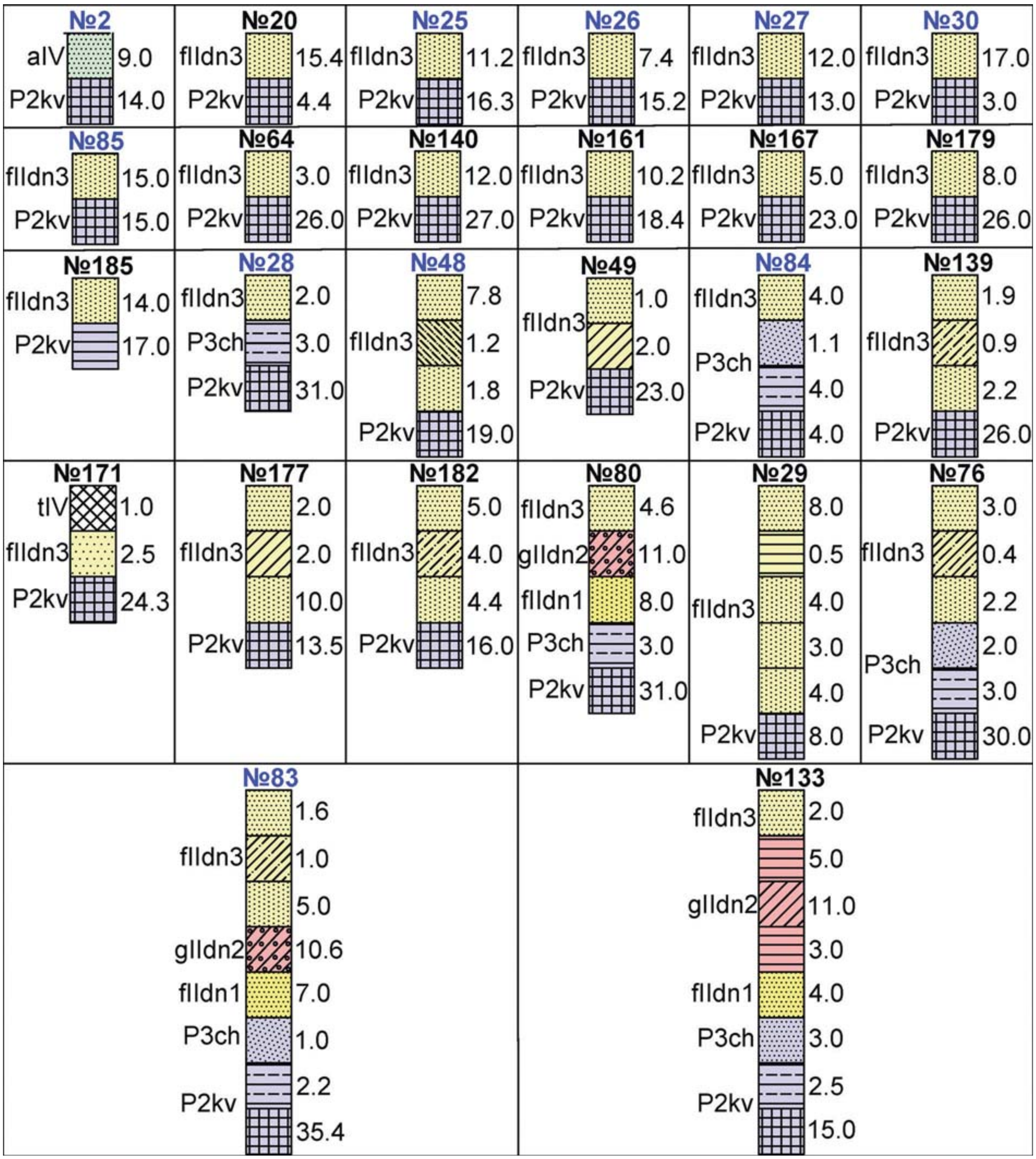

Fig. 2. Geological-lithological columns by wells.

eas of the watershed has an average degree of alkaline aggressiveness towards concrete (II types of corrosion) and is confined to the lower parts with depths of up to 1 m — strong sulfate aggressiveness (III type of corrosion). The pH value varies from 6 to 7.5, and the total hardness from 2.0 to 19.6 mg/eq. The waters are clear, odorless and colorless, their temperature in the summer varies between 8—12 °C.

The aquifer complex is widely used by the population for domestic water supply with the help of mine wells and individual wells. The flow rates of wells are 0.02—0.06 l/s [Rudenko et al., 1971; Tsybko, 2020].

The aquifer complex in the Bucha-Kaniv sediments (P_2bc-kn) is widespread and is the main horizon for the centralized water supply of the city. The aquifer deposits of the Bucha suite in the city's territory are represented to varying degrees by clayey, multi-grained (mainly fine-grained) sands with a thickness of 20—25 m. The deposits of the Kaniv suite are represented by sandy-clay deposits with a predominance of sand. The sands are fine-grained, clayey with underlying layers of siltstones and clays. In general, the aquifer rocks of the Eocene complex represent a fairly homogeneous sand-clay stratum. The total capacity is 25—35 m.

The filtration coefficients of these sediments range from 2 to 8 m/day. Piezoconductivity coefficients are $4.3 \cdot 10^4$—$5.4 \cdot 10^5$ m^2/day. The marl-chalk stratum of the Upper Cretaceous lies at the base of aquifer Eocene sediments. This stratum is a relative water barrier separating the Eocene and Cenomanian aquifers. The thickness of the marl-chalk layer increases from southwest to northeast from 0 to 22.0 m. The marl-chalk stratum is absent in the southwestern part outside the city limits and there is a direct hydraulic connection with the underlying Cenomanian aquifer. The marl-chalk stratum is characterized by

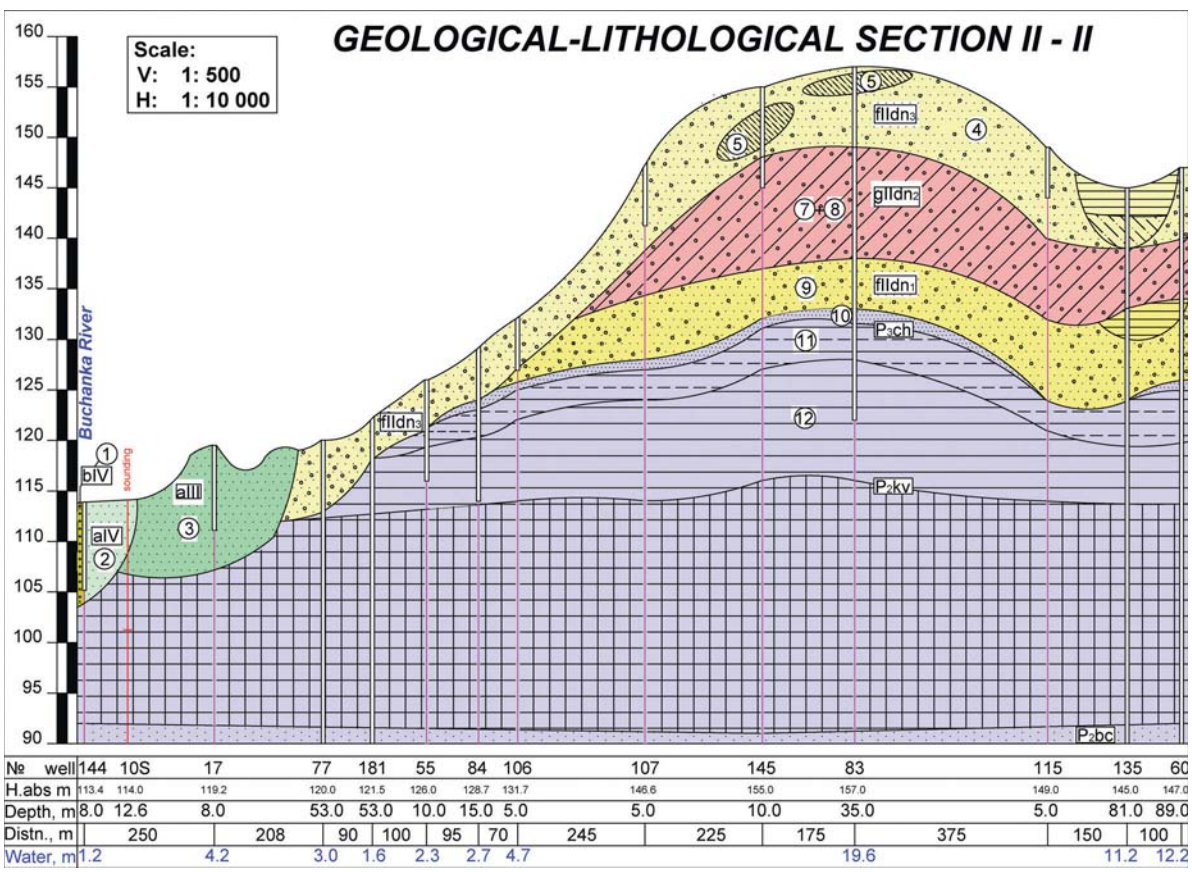

Fig. 3. Typical geological-lithological section on Irpin city along conditional line II—II.

a particularly high permeability due to the continuous planar development of tectonic damage. The aquifer of Eocene sediments in the studied area has a hydraulic connection with the Cenomanian aquifer in this regard.

The sediments of the Kyiv suite (marls and siltstones) lie on the roof of the Eocene aquifer complex. Their power varies from 4—5 m at the Irpin River floodplain up to 20—25 m in watershed areas. The filtration coefficients of Kyiv marls vary from $2.5·10^{-4}$ to $3.9·10^{-4}$ m/day according to laboratory research.

The depth of the aquifer complex varies from 20 to 85 m within the limits of the Makariv moraine water-glacial plain. The absolute marks of its roof decrease in the northeastern direction from +95 to +60 m.

The aquifer is under pressure. The pressure above the roof of the aquifer within the plain is 11—35 m. Piezometric levels are set at absolute marks of 105—126 m. Flow rates of wells range from 1.5 to 4.5 l/s, flow rates of individual existing wells are 8—10 l/s, and specific flow rates are 0.08—1.8 l/s.

They belong to the bicarbonate-calcium water according to the chemical composition of the water. Their mineralization does not exceed 0.6 g/l. The hardness varies from 2.3 to 6.5 mg/eq. The reaction of water is weakly acidic and close to neutral. The pH ranges from 7.2 to 8.1. Bacterially, the water is clean. The quality of the water in general meets the requirements for drinking water. The relative shallowness of the Eocene aquifer complex, sufficiently high flow rates of the wells and good drinking qualities determine its use for water supply in Irpin city [Bogatyrenko et al., 2019; Tsybko, 2020].

The Cenomanian aquifer (K_2Cm) is widely distributed in the described territory. Aquifer rocks are represented by fine-grained sands, often clayey, containing layers and lenses of fine-grained sands, siltstones and marls. The thickness of the aquifer varies from 6.5 to 15.0 m with an average of 10—12 m. The filtration coefficient of water-bearing rocks is 1—3 m/day. The piezoconductivity coefficient is $4.7·10^4$—$7.5·10^5$ m^2/day. The depth of the aquifer's roof varies from 25 to 78 m. In the aquifer's roof lies a marl-chalk stratum of the Upper Chalk. The thickness of these deposits within the studied area is from 0 to 22.0 m, being 7.5—12.0 m in the area of Irpin. These rocks separate the Cenomanian horizon from the overlying aquifer.

The marl-chalk stratum is characterized by a relatively high permeability due to the continuous planar development of tectonic disturbances. The value of the filtration coefficient determined by the laboratory method is 0.1—0.001 m/day. The aquifer of Cenomanian sediments has a hydraulic connection with the Eocene aquifer in the entire considered territory.

There is no marl-chalk stratum and there is a direct hydraulic connection with the overlying Eocene aquifer in the southwestern part of the described territory.

The aquifer rocks of the Cenomanian aquifer lie on the sediments of the Upper and Middle Kelowian and are underlain by Bath clays, forming a single regional Jurassic aquifer, the thickness of which reaches 140 m and increases from the southwest to the northeast.

The presence of an aquifer Turon marl-chalk layer in the aquifer's roof determines the groundwater's pressure nature. The amount of pressure above the roof is 51.5—67.0 m. Levels in the wells are set at the depth of 1.0—38.3 m. Flow rates of wells equipped for the Cenomanian aquifer are 2.5—6.4 l/s when the level drops by 10—32 m. Specific flow rates are 0.11—0.27 l/s. Piezoconductivity coefficients are 10^4—10^5 m^2/day according to experimental works.

The waters of the Cenomanian aquifer are fresh hydrocarbonate-calcium-magnesium with a mineralization of 0.3—0.4 g/l. The total hardness of water varies no more than 3.7—4.8 mg/eq. The aquifer is exploited for water supply by the population and industrial enterprises [Romashchenko et al., 2015; Tsybko, 2020].

The fractured zone's aquifer complex of Precambrian crystalline rocks (A-Pt) is widespread in the described territory. Precambrian crystalline rocks in the area of Irpin lie at a depth of 170—290 m. The aquifer rocks are: Archean gneisses and amphibolites, granites, Archean-Proterozoic migmatites. The weathering crust lying on the crystalline rocks has a rather wide development and is mainly represented by primary kaolins, which are a water barrier and separate aquifers of the sedimentary stratum and the fractured zone of crystalline rocks (Fig. 4).

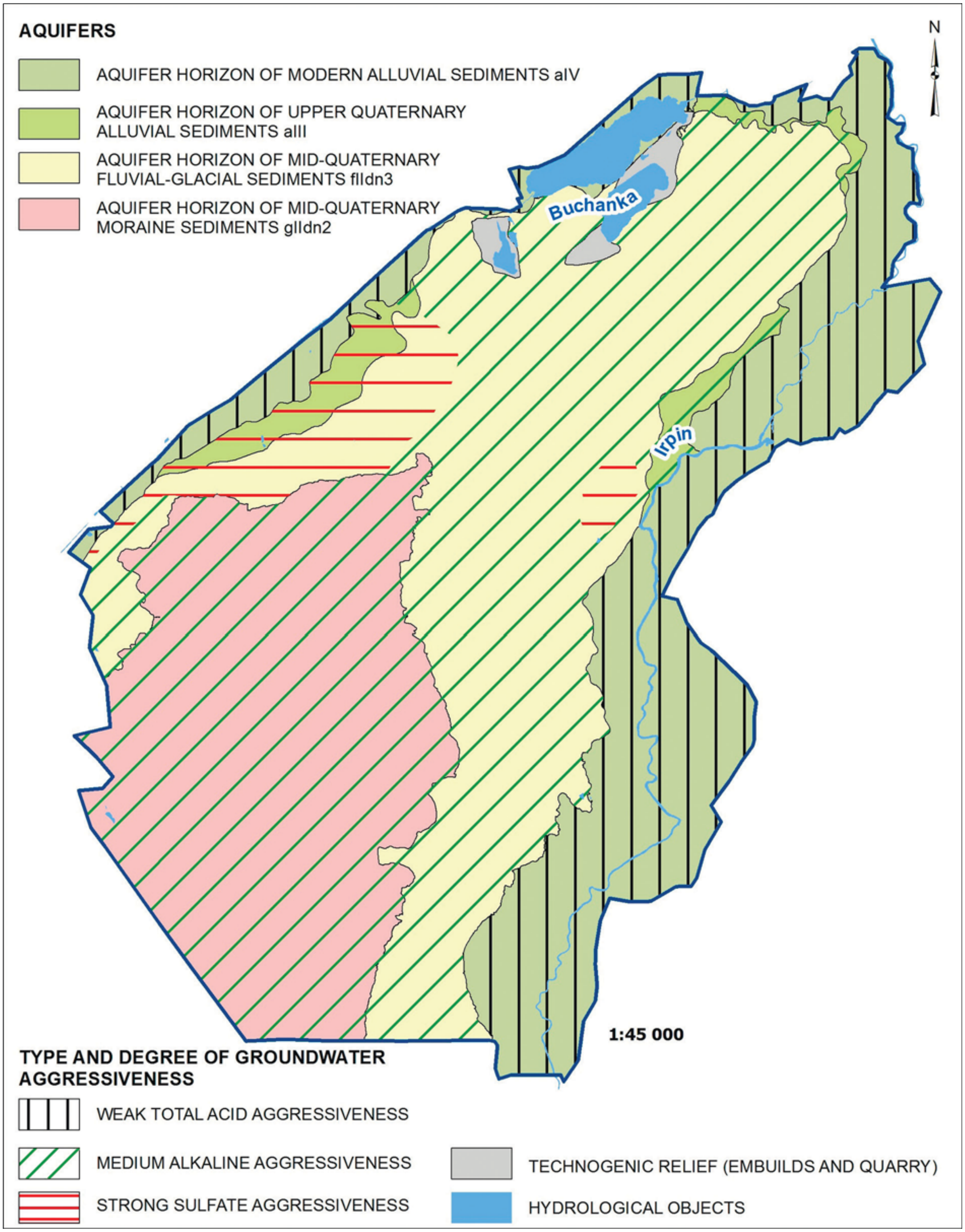

Fig. 4. Hydrogeological map of Irpin city.

The aquifer of the fractured zone has a hydraulic connection with the overlying aquifer in places where there is no weathering crust. The water content of aquifer crystalline rocks depends on the degree of fracturing. Flow rates of wells are 0.024—0.440 l/s. Typical flow

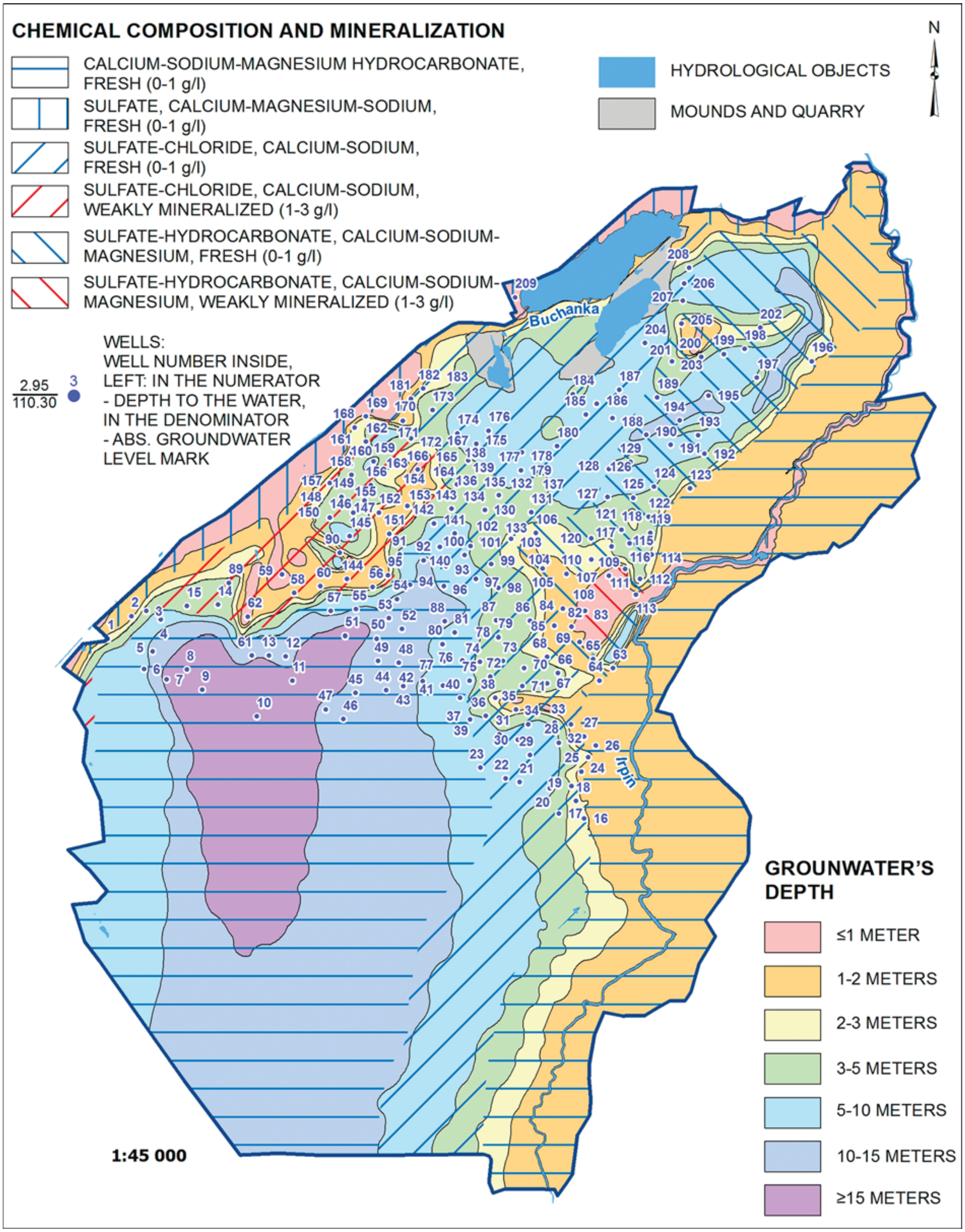

Fig. 5. Map of groundwater depth and chemistryof Irpin city.

rates are 0.017—0.217 l/s. The aquifer is under pressure and the amount of pressure within the plain ranges from 2 to 82 m. Piezometric levels are set at a depth of 1.5 to 41.0 m.

The fractured zone's waters of crystalline rocks are medium hardness and hard, sometimes soft. The value of the total hardness varies in the range of 2.04—8.15 mg/eq. The

2.36/116.90 (1)	1.29/118.01 (2)	3.50/120.80 (3)	7.79/124.71 (4)	12.12/124.33 (5)	5.55/125.95 (6)	16.05/130.42 (7)	18.35/133.70 (8)	19.50/135.50 (9)	23.60/136.20 (10)
20.09/136.71 (11)	11.02/144.08 (12)	16.26/136.50 (13)	2.42/129.38 (14)	3.68/127.82 (15)	2.20/111.0 (16)	3.38/111.42 (17)	2.00/111.00 (18)	2.72/110.68 (19)	5.29/111.18 (20)
8.71/113.04 (21)	8.14/114.76 (22)	6.87/118.08 (23)	1.14/111.80 (24)	1.14/114.40 (25)	1.54/111.00 (26)	1.36/111.14 (27)	4.88/111.12 (28)	6.48/113.02 (29)	4.58/117.32 (30)
5.24/118.31 (31)	1.15/111.60 (32)	4.83/111.92 (33)	5.16/116.84 (34)	1.79/118.81 (35)	5.02/119.03 (36)	5.10/119.45 (37)	2.43/119.02 (38)	6.10/119.97 (39)	5.71/120.04 (40)
6.56/121.84 (41)	9.43/123.17 (42)	12.14/126.46 (43)	5.14/129.33 (44)	11.98/134.92 (45)	10.93/136.57 (46)	12.25/135.11 (47)	14.35/127.05 (48)	8.62/131.78 (49)	11.17/131.32 (50)
19.62/134.10 (51)	13.53/126.85 (52)	11.68/128.47 (53)	12.02/128.48 (54)	12.77/128.53 (55)	0.71/130.00 (56)	8.76/135.34 (57)	1.45/130.55 (58)	0.37/124.00 (59)	1.05/29.95 (60)
13.41/137.04 (61)	0.72/131.68 (62)	2.75/110.90 (63)	1.80/110.30 (64)	1.58/110.87 (65)	3.41/115.59 (66)	4.50/115.15 (67)	2.75/117.55 (68)	1.69/111.71 (69)	4.00/118.60 (70)
3.60/119.60 (71)	3.64/119.16 (72)	3.17/119.13 (73)	4.64/120.40 (74)	5.83/120.17 (75)	6.89/120.61 (76)	7.82/121.73 (77)	5.53/120.72 (78)	4.69/118.81 (79)	7.93/122.00 (80)
7.90/120.55 (81)	0.98/114.00 (82)	0.66/111.64 (83)	2.05/116.55 (84)	1.14/116.88 (85)	4.72/118.88 (86)	3.80/119.75 (87)	12.49/121.71 (88)	5.0/120.15 (89)	5.65/122.05 (90)
5.32/125.88 (91)	12.10/124.15 (92)	8.40/121.43 (93)	8.94/127.96 (94)	1.90/129.85 (95)	9.70/121.50 (96)	6.40/120.10 (97)	4.03/119.97 (98)	3.40/119.15 (99)	6.53/120.65 (100)
6.40/120.13 (101)	3.25/120.33 (102)	2.86/119.44 (103)	1.86/119.44 (104)	1.69/119.31 (105)	2.29/118.51 (106)	1.56/117.20 (107)	0.18/116.90 (108)	0.86/113.20 (109)	2.21/115.29 (110)
1.00/112.50 (111)	3.25/110.20 (112)	0.90/110.05 (113)	3.25/111.30 (114)	5.23/110.42 (115)	4.07/112.43 (116)	2.38/114.87 (117)	5.38/112.67 (118)	4.78/112.02 (119)	3.49/115.91 (120)
2.35/112.67 (121)	5.15/110.80 (122)	1.60/109.45 (123)	5.91/109.44 (124)	4.90/112.65 (125)	6.70/110.80 (126)	5.19/114.61 (127)	6.57/113.43 (128)	4.02/113.78 (129)	3.50/119.05 (130)
3.32/117.68 (131)	3.42/119.48 (132)	4.17/119.33 (133)	4.05/120.40 (134)	4.72/120.5 (135)	4.59/120.40 (136)	4.15/119.10 (137)	4.77/121.65 (138)	4.45/121.65 (139)	7.75/122.81 (140)
5.74/121.18 (141)	6.29/122.67 (142)	4.72/120.58 (143)	0.45/131.05 (144)	6.80/118.00 (145)	3.24/114.36 (146)	4.19/113.56 (147)	2.85/112.15 (148)	3.91/113.19 (149)	3.49/113.71 (150)
1.04/123.46 (151)	1.69/121.63 (152)	1.13/123.60 (153)	2.63/122.87 (154)	4.93/115.97 (155)	3.59/115.96 (156)	2.70/112.28 (157)	3.98/112.00 (158)	5.70/111.45 (159)	3.24/112.48 (160)
3.39/112.06 (161)	2.89/112.00 (162)	4.26/112.33 (163)	3.82/121.78 (164)	3.81/120.37 (165)	0.81/120.90 (166)	3.89/121.23 (167)	2.41/111.34 (168)	3.90/110.43 (169)	2.35/110.35 (170)
1.94/114.91 (171)	3.67/117.33 (172)	3.82/119.68 (173)	5.77/121.33 (174)	6.45/121.77 (175)	7.77/120.33 (176)	7.86/120.34 (177)	8.00/118.20 (178)	7.60/120.27 (179)	7.37/115.48 (180)
1.90/114.09 (181)	3.40/115.30 (182)	1.74/109.02 (183)	2.24/121.44 (184)	5.59/119.61 (185)	2.80/117.85 (186)	5.37/119.23 (187)	5.69/118.86 (188)	5.25/117.75 (189)	11.02/114.18 (190)
8.17/112.28 (191)	5.30/110.73 (192)	8.53/112.57 (193)	10.65/114.70 (194)	10.00/116.93 (195)	2.69/116.90 (196)	3.50/108.78 (197)	5.20/108.70 (198)	7.22/108.78 (199)	4.55/112..65 (200)
2.96/117.04 (201)	2.48/118.24 (202)	5.20/118.70 (203)	11.59/118.96 (204)	1.44/116.81 (205)	4.75/109.30 (206)	5.26/110.74 (207)	3.02/109.43 (208)	1.74/109.02 (209)	

Fig. 6. Data of hydrogeological observation points (wells).

reaction of water is close to neutral [Tsybko, 2020].

Influence of hydrogeological conditions on the engineering protection of Irpin city. Therefore, underground waters with different types and degrees of aggressiveness are present in the Irpin's subsoils, which requires special measures for their neutralization (Fig. 5, 6, Table 1).

There are areas with a level of groundwater lying first from the surface from 0.2 to 3.0 meters, which correspond to the subzones of strong, moderate and weak underflooding [Davybida, 2014]. The underflooding process is characteristic of the floodplains of the Irpin and Buchanka Rivers, their first floodplain terraces, within the gully network, as well as in local areas of the watershed for natural and technogenic reasons. The composition of groundwater is mainly sulfate-hydrocarbonate and sulfate-chloride calcium-sodium-magnesium, fresh, although there are local areas with weakly mineralized groundwater. Engineering protection measures must be taken during urban development of the specified territories [National..., 2010; State..., 2010] (Table 2).

Discussion. At this stage, the hydrogeological maps made it possible to take into account the areas of sites' distribution with different degrees of groundwater aggressiveness, mineralization and depths of the first aquifer from the surface. The specified maps can be used for designing an engineering-construction assessment scheme for Irpin city and identifying unsuitable areas for construction (Table 3) [State..., 2008].

Qualitative engineering building assessment should be a priority for design engineers as part of draft master plans' settlements [Gubenko et al., 2017]. Here are the most basic hydrogeological factors that must be taken into account for engineering-construction assessment, but the specified categories are not complete and exhaustive. The authors call on all interested specialists for a scientific discussion and consensus for solving this problem.

Conclusions. The conducted study of the hydrogeological conditions of Irpin city makes it possible to build appropriate maps

T a b l e 1. Type of groundwater aggressiveness and measures to their neutralization

Type of groundwater aggressiveness	Characteristic	Measures for neutralization
Total acid aggressiveness	The water's pH is less than 6. The calcium carbonate's solubility increases. The aggressiveness of water is different depending on the cement's brand and pH values: at pH<4 it is the most aggressive, at pH=6.5 is the least.	Vertical planning of the territory, installation of drainage system sandstorm sewers, isolation of structures' foundations from underground water using clay castles made of compacted clay in combination with bitumen, installation of ditches around structures with lime stone or crushed stone, which neutralize acid sand reduce the water's level of aggressiveness, erection foundations, underground structures and their elements using concrete with increased chemical resistance, application of roll and bitumen water proofing, facing with clinker bricks using an acid-resistant solution or bitumen, using chemically resistant shells, protecting surface structures with paint coatings, zinc coatings, methods of hot or cold galvanizing or gas thermal spraying, treatment with hydrophobic solutions, biocides.
Alkaline aggressiveness	Water contains more than 0.4—1.5 mg/eq. bicarbonate. It manifests itself in the calcium carbonate's dissolution and the calcium hydroxide's removal from concrete. The degree of aggressiveness of water is determined by the calcium carbonate's solubility. The calcium hydroxide's removal increases in the presence of magnesium chloride, which enters into an exchange reaction with calcium hydroxide, forming a highly soluble calcium chloride.	
Sulfate aggressiveness	Water contains over 250 mg/l of sulfate ions. Sulfate ions present in water in high concentrations, penetrating into concrete, form calcium sulfate crystalline hydrate during crystallization, which is the cause of concrete's swelling and destruction.	

Table 2. Measures for engineering protection of under-flooding areas

Kind of measures	Characteristic
Precautions	1) Avoidance of the development of the Buchanka River's flood plains by Article 80 of Ukraine's Watercode; 2) Installation of infiltration sites with water-permeable coatings; 3) Direct protection of foundations of buried houses, buildings and structures using waterproofing materials, construction of foundations of buried structures from waterproof concrete, use of internal drainage; 4) Prevention of losses from water-bearing communications; 5) Installation of anti-filtration curtains and screens; 6) Use of drains during construction.
Installation of protective structures	1) Arrangement of horizontal tubular drainage; 2) Arrangement of flat, vertical, combined, radial, or vacuum drainage.
Monitoring of the underground hydrosphere	1) Survey of areas prone to under flooding; 2) Survey of the state of engineering protection structures existing in the under-flooding territories; 3) Determination of available sources of under flooding; 4) Observation of the hydrogeological regime of underground waters by forming a network of observational hydrogeological wells (piezometers).

Table 3. Category of hydrogeological conditions' complexity and construction assessment for Irpin city

Hydrogeological factors in the sphere of the interaction of buildings and structures with the geological environment	
I (easy) — 0 points	There is no underground water or there is one sustained underground water horizon with a homogeneous chemical composition
II (average) — 1 point	Two or more sustained underground horizons waters, locally with a heterogeneous chemical composition or with pressure
III (high) — 2 points	Groundwater horizons are not sustained in terms of occurrence and capacity, with a heterogeneous chemical composition; sometimes complex alternation of the aquifer and water-resistant rocks; groundwater pressures change with their depth
The degree of groundwater's aggressiveness	
I (easy) — 0 points	Absence or weak
II (average) — 1 point	Medium
III (high) — 2 points	Strong
Mineralization degree	
I (easy) — 0 points	Fresh (to 1g/l)
II (average) — 1 point	Weakly mineralized (from 1 to 10 g/l)
III (high) — 2 points	Highly mineralized (≥10 g/l)
Groundwater's depth	
I (easy) — 0 points	≥3 m
II (average) — 1 point	2—3 m
III (high) — 2 points	≤1 m
Sum of points and construction assessment	
I (easy) — Suitable for construction	0—2 points
II (average) — Little use for construction	3—5 points
III (high) — Useless for construction	≥6 points

and identify distribution areas of mineralized, aggressive and close to the earth's surface groundwater and as a result to choose appropriate methods of protecting reinforced concrete structures from the specified harmful hydrogeological factors and to design a high-quality scheme of construction assessment.

This approach provides an informative tool for urban planning projects and offers an overview of the issues and important indicators for engineering protection and the corresponding territory's engineering-construction assessment. Emerging problems can be identified on special hydrogeological maps and then investigated in detail by various specialists.

Our approach should be further supported by detailed geomorphological and engineering geological data otherwise the choice of engineering protection measures will be unfounded and sites' selection by the degree of suitability during construction assessment will not be completely correct (research is not finished at the moment).

References

Alekseev, Yu.N. (1980). *Engineering geological zoning of Kyiv region for land reclamation construction.* Kyiv: Budivelnyk, 128 p. (in Russian).

Bogatyrenko, V.A., Kalinin, I.V., & Bylenko, M.A. (2019).Study of the dynamic character of carbonate-calcium groundwater balance of Kyiv region. Section 8. Ecological and economic aspects of rational water use: *Materials of the III International scientific and practical conference, 14¾15 November 2019, Kyiv* (pp. 176—180) (in Ukrainian).

Davybida, L.I. (2014). Creation of regional forecasts and geoinformation models of the levels of groundwater's depth. *Scientific journal IFNTUNG, 1*(36), 26—35 (in Ukrainian).

Gubenko, T.V., Mukha, V.G., & Kozyna, N.P. (2017). *Master plan of Irpin city.* Kyiv: Dipromisto, 180 p. (in Ukrainian).

Ivanenko, P.I. (2020). *State geological map of Ukraine — 200*. Kyiv: Ukrgeoinform, 67 p. (in Ukrainian).

Kostyuchenko, M.M., & Shabatyn, V.S. (2005). *Hydrogeology and engineering geology.* Kyiv: Kyiv University Press, 144 p. (in Ukrainian).

National standard of Ukraine SSU-N B V.1.1-XX: 2010. (2010). *Engineering protection of territories, houses, buildings and structures against underflooding and flooding.* Kyiv: Minregion, 203 p. (in Ukrainian).

Panchenko, T.S. (2019). *Geological map of Ukraine.* Kyiv: Ukrgeoinform, 75 p. (in Ukrainian).

Romashchenko, M.I., Shevchenko, A.M., & Zabuga, A.O. (2015).State and prospects of the use of irrigated land Irpin river basins. *Reclamation and water management, 102,* 37—44 (in Ukrainian).

Rudenko, F.A., Solyakov, I.P. & Mesyats, I.A. (1971).*Hydrogeology of USSR*. Moscow: Nedra, 614 p. (in Russian).

Slynko, O.V. (1992). On the regulatory framework for hydrogeological research in engineering surveys for the construction and protection of the territory from underflooding. *Engineering geology, 1*, 90—97 (in Russian).

Solovytsky, V.N., & Vozgryn, B.D. (1990).*The geological map on the scale 1:50 000 by sheets of Kyiv region.* Kyiv: Ukrgeolstrom, 10 p. (in Ukrainian).

State building norms A.2.1-1-2008.Engineering exploration for construction. (2008). Kyiv: Minregion, 72 p. (in Ukrainian).

State building norms B.1.1-15:2012.Structure and contents of master plan's settlement. (2012). Kyiv: Minregion, 33 p. (in Ukrainian).

State building norms B.1.1-25-2009.Engineering protection territory and building of underflooding and flooding. (2010). Kyiv: Minregion, 52 p. (in Ukrainian).

Tsybko, V.A. (2020). *Engineering geological atlas of Irpin city on the scale 1:5000*. Kyiv: UKRIINTR, 97 p. (in Ukrainian).

Гідрогеологічні умови Ірпеня та їх вплив на організацію інженерного захисту та будівельне оцінювання міста

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Державними будівельними нормами визначено, що при розроблені проєктів генеральних планів населених пунктів серед додаткових графічних матеріалів бажана схема інженерно-будівельного оцінювання норм [Державні…, 2012], яка створюється на підставі інженерно-геологічного районування території міста. Це передбачає виділення різнорангових інженерно-геологічних таксономічних одиниць, що володіють певним набором спільних інженерно-геологічних умов, які в кінцевому випадку визначають приналежність будівельних ділянок до певної категорії придатності. У статті досліджено геолого-літологічну будову та гідрогеологічні умови м. Ірпінь Київської області, виділено типи та ступені агресивності, хімічного складу та мінералізації підземних вод, глибин залягання перших водоносних горизонтів від денної поверхні. На основі проведення гідрогеологічного знімання представлений варіант побудови великомасштабних карт хімізму та глибин залягання підземних вод. Аналіз гідрогеологічних особливостей території міста закладає основи для виділення інженерно-геологічних ділянок шляхом зіставлення цієї інформації з геоморфологічними, інженерно-геологічними та геодинамічними даними.

Кінцевим результатом стало комплексне оцінювання гідрогеологічних умов та врахування гідрогеологічних факторів для схеми інженерно-будівельного оцінювання та підбору відповідних заходів щодо інженерної підготовки та захисту проблемних будівельних майданчиків м. Ірпінь.

Ключові слова: гідрогеологічні умови, геолого-літологічна будова, гідрогеологічні карти, інженерний захист, будівельне оцінювання.