A Visit to Eastern Europe: Urban Drainage Conference & ASCE Technical Visitations

A direct exchange of information on new techniques or projects can help in developing greater insights that could be successfully integrated into current practice.

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Given the scale and cost of the project to clean up Boston Harbor, it is a distinct advantage to remain current on concepts and technologies that may be effectively implemented in solving a major source of pollution in the harbor — namely, combined sewer overflows. The New Technologies in Urban Drainage Conference (UDT 91) in June 1991 at Dubrovnik, Yugoslavia, provided an opportunity to learn about recent developments first-hand. In addition, the associated American Society of Civil Engineers (ASCE) Technical Visitation Program provided an exchange of information on current, and anticipated, practices (as well as constraints on practices) in Austria, Hungary and Czechoslovakia.

New Technologies in Urban Drainage Conference

At UDT 91, new developments in meteorological and hydrological data measurement and collection were presented as well as information on system control and modeling.

Rainfall Quantity & Quality

On October 3, 1988, over 26 centimeters (10.2 inches) of rain fell on the small village of Nimes, France, in less than five hours.[1] European engineers are still amazed at the volume of this short-duration storm. Using this event as a backdrop, the European design community is looking into the value of an historical rain series method *versus* a statistical analysis method.

The historical streamflow method is difficult to establish for many locations in Europe. This difficulty is due, in part, to the lack of sufficient long-term stream gaging on catchments of diverse sizes and geographic characteristics. It is also due, in part, to the language differences within and across geographic regions. How-

TABLE 1
Number & Density of Rain Gage Stations in Yugoslavia

	Observation Period in Years				
	40	**35**	**30**	**25**	**20**
Number of Stations	11	35	74	118	156
Density (km^2/Station)	23,254	7,308	3,457	2,167	1,639

ever, European hydrologists are beginning to turn to statistical methods based on rainfall measurements.

These methods use rainfall intensity-frequency-duration records to synthesize streamflow. During a discussion of the European part of the Mediterranean Basin, it was pointed out that many countries have not conducted comprehensive statistical analyses of short-duration storms. One presenter at the conference stated that: "According to some of our colleagues at Italian universities, no synthetic information, on a national basis, yet exists for Italy."[2] While each country has performed some sort of rainfall analysis, there appears to be a lack of coordination among countries in definite geographic regions to share data in order to undertake more meaningful analyses.

Rainfall analysis in Europe varies from country to country. For example, Yugoslavia is lacking long-term rain gage data as shown in Table 1. When the data are available, conventional intensity-duration-return (IDR) curves have been used to determine dimensionless hyetographs (rainfall rate *versus* time curves) with a given probability.[3] The drainage engineer must then, of course, design appropriate storage facilities and evaluate water quality on a range of design storm durations.

The European Community is becoming increasingly wary of the effects of industrialization on their atmosphere. Surprisingly, in an evaluation of the rainwater quality at Toulouse, France, increased levels of cadmium of essentially atmospheric origin were found in rainwater samples collected from five locations over a period of time. However, acid rain does not appear in any significant way in rainfall collected in Toulouse.[4]

Application of Radar & Satellites

European engineers make extensive use of weather radar in sewer system management, including wastewater treatment facility operation. The weather radar systems are used for general forecasting and are organized on a country-by-country basis. Sewer operators also are installing weather radar facilities for their own short-term forecasting requirements.

Hydrologists involved with sewer system design and operation are investigating the optimization of radar locations, the suitability of operating protocol, and the collection and distribution of information.[5] For example, the Seine-Saint-Denis county (greater Paris area) real time control system (RTCS) for pollution control and flood prevention has been operating since 1982. The RTCS includes more than 100 remote control stations. About 70 percent of these stations transmit alarms and measurements; the remainder are regulating stations that perform tasks or computations automatically. More than 2,000 data points are available at the control center, providing meteorological updates every five minutes. Rainfall forecasts are also updated at five-minute intervals using a second moments cloud tracking model.[6]

Another example of the application of a weather radar system to a drainage system is provided by the Tokyo Metropolitan Sewer System. As shown in Figure 1, two radar stations have been installed as part of the sewer system. The weather radar stations have a radius of 40 kilometers (25 miles) and are divided to furnish a mesh coverage of 20,480 units. Each unit covers about 500 square meters (1,600 square feet). The radar rainfall information is sent to a central processing unit along with data from 41 rain gaging stations. Operators use this information to operate the system's 67 pump stations and ten wastewater treatment plants. The system engineers are presently studying the possibility of a forecast system that incorporates real time control in order to assist pump station operation.[7] This weather radar system is part of a greater sewer system operation plan

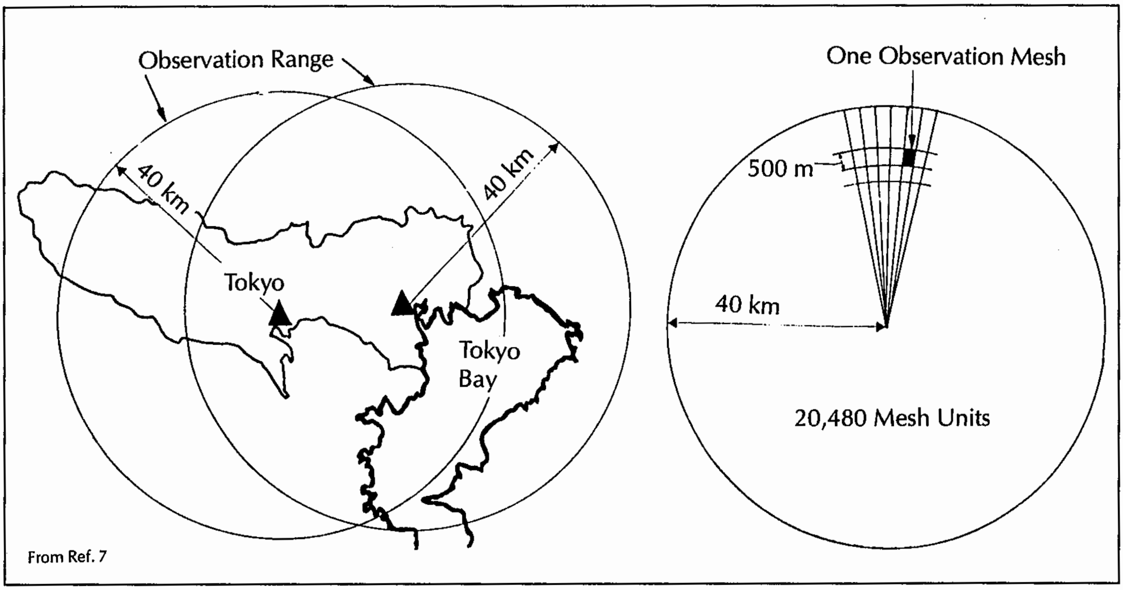

FIGURE 1. Observation range of the Tokyo radar rain gage system and the mesh formation of the radar observation coverage.

that includes a sewerage mapping and information system.

Flow Measurement & Data Acquisition Systems

Datalogging and data acquisition systems are required for the analysis of sewer system operation. The data are used to calibrate and verify simulation models. The conference stressed that good data acquisition systems require a careful study that encompasses planning, bidding, installation, testing and monitoring operation. For the village of Fehraldorf in Switzerland, which has a population of 5,000 and has five combined sewer overflows, Table 2 presents the resources that were needed to establish a good data acquisition system.

In another interesting area of data acquisition, French engineers have been testing the validity of ultrasonic measurement of velocity. Their results have shown that current technology provides a measurement accuracy range from one to seven percent. This degree of accuracy is based on proper installation and adequate calibration of the ultrasonic sensors.[9]

New Approaches in Rainfall-Runoff Modeling

The use of the rational method for the design of storm sewers is popular worldwide. This method utilizes a terrain-based runoff coefficient, *C*, to calculate the runoff rate from a storm

TABLE 2
Resources Needed for a Medium-Sized Data Acqusition System[8]

Phase	Resource(s)
Planning	60 Man Days, City Engineer 120 Man Days, Consulting Engr.
Bidding	240 man days
Installation	$23,700, 6 Rain Gages $11,900, Equipment $59,000, Central Data Transmission 150 Man Days
Testing	$6,000, Testing Equipment 270 Man Days
Operation	2 Part-Time Technicians Routine Operation of 1 Rain Gage 13 Water Level Gages 1 Electromagnetic Flow Meter 2 Sluice Gates 3 Diversions 3 Pumps

event of known or assumed rainfall intensity and drainage area. But this method poses the problem of whether the catchment response is constant for different storm events — *i.e.,* whether the C value really is a constant. Several hydrologists feel that assuming a constant response may lead to significant errors. Therefore, they suggest alternative design methods. These methods include kinematic wave theory,[10] nonlinear programming,[11] diffuse wave theory (also known as the Belgrade model of urban sewers [BEMUS])[12] and finite element modeling.[13]

Many European designers are using a program developed by the Danish Hydraulic Institute to design their storm sewers.[13] This modeling program uses a modified diffusive wave approximation for computing runoff and provides extensive graphic capabilities along with a very user-friendly interface.

Water Quality in Sewer Systems & in Receiving Waters

Recently, drainage system design throughout the world has been focusing on receiving water quality. Adding advection and diffusion processes to hydrodynamic and sediment transport models has changed the modeling of the receiving waters.[14]

Sewer design engineers worldwide are now perceiving a trend toward integrating system components — such as the catchment, runoff system, wastewater treatment plant *and* receiving waters — into a total design plan. The shift is now to designing in order to ensure total system performance.[15] Thus, focusing on the receiving water quality requires that the entire system be evaluated. One U.S. Environmental Protection Agency (EPA) official has called for integrated stormwater management and has stated that effective wet-weather pollution methodology must take into consideration:[16]

- The effects of wet-weather pollution in lieu of blindly upgrading existing municipal wastewater treatment plants;
- Structural *versus* nonstructural techniques;
- Integrating systems and controls in order to maximize use of previously existing systems; and,
- The percent of pollution controlled *versus* cost curve.

Real Time Control

An urban drainage system (UDS) is operated in real time if process data, which is currently monitored in the system, is used to control regulators during the actual sewer system operation (see "The Feasibility of Real Time Control of Combined Sewer Overflows" on pages 17 to 26 of this issue for a longer discussion of real time control).[17] This type of UDS operation is dynamic and not static. For example, a static sewer could be designed for a ten-year storm of a given duration and with a uniform areal rainfall. Rainfall isohyetal graphs usually show that rainfall is not uniform, but that numerous peaks in rainfall occur at different times and places within the sewer system's area. Thus, in the design storm, overflows occur in certain areas while there is unused capacity in other areas. Remembering that the catchment area does not react in a constant fashion to various storm events, it is evident that dynamic system operation can be a truly effective pollution abatement method.

With the publication of the U.S. EPA's "Final National Combined Sewer Overflow (CSO) Control Strategy" in August 1989, many water treatment authorities in the U.S. are now looking to real time control to contribute to the solution of their CSO problems. Real time control has been applied to sewer collection systems in Europe with successful results.[18] In the city of Ense-Bremen, in Germany, an RTCS has been applied to an existing sewer system that has six detention facilities in a semi-urban catchment (see Figure 2). The control of flows throughout the system and into the treatment plant is executed by both local and remote systems. A data acquisition system is used to monitor operational status as a storm passes over the catchment. The system's objective is to optimize existing wastewater storage and treatment capacities throughout the storm event. Weyland and Dohmann summarize the RTCS's design goal:

> "The aim of the real time control system which is applied in the sewerage of Ense-Bremen is the management of flow and stor-

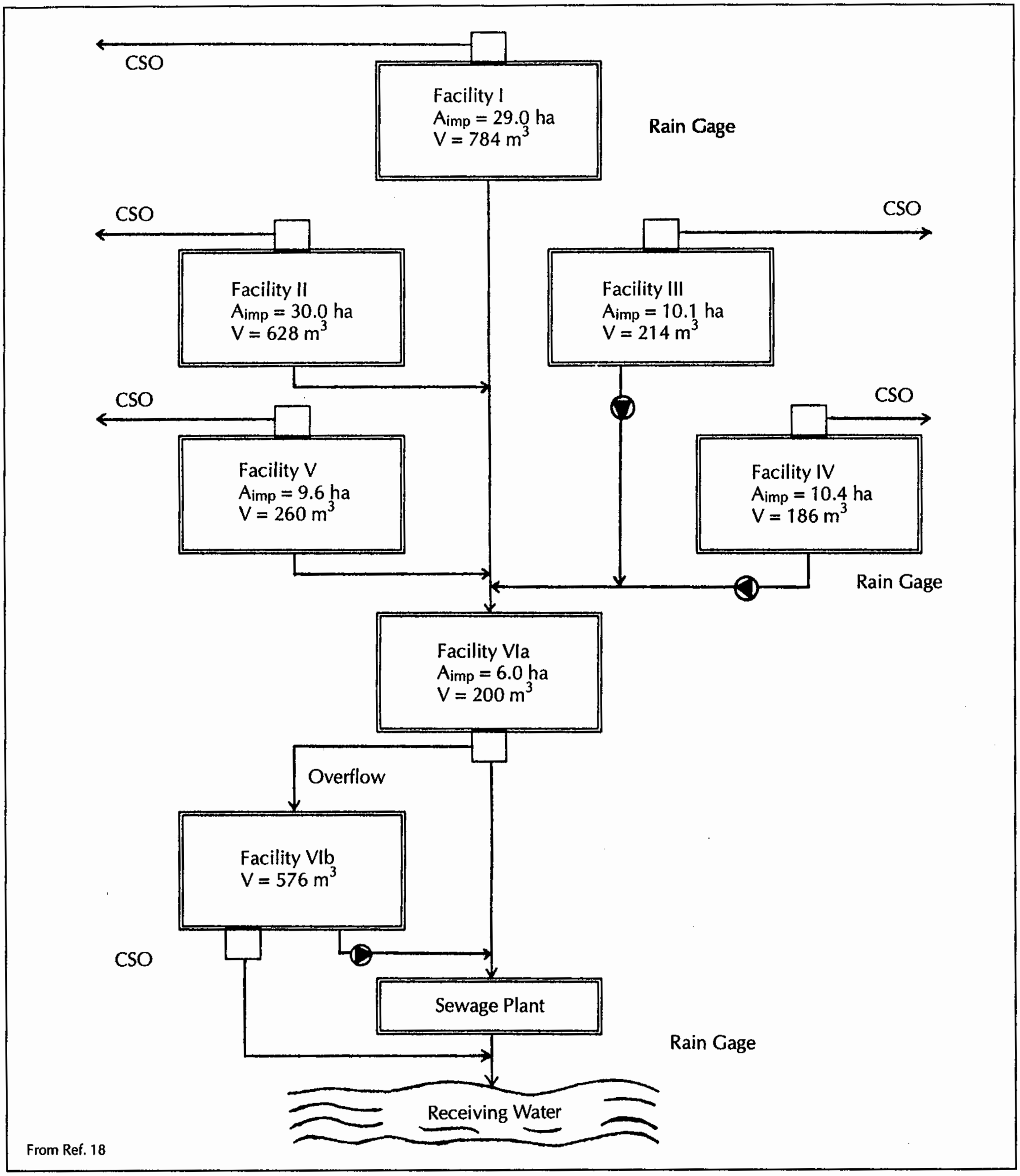

FIGURE 2. Schematic of the Ense-Bremen combined sewer system.

age events in such a way that an even degree of storage capacity should be achieved at any detention tank at any time. Thus, a discharge of CSO into the receiving waters should first occur if all available storage volume is completely filled."[18]

In an RTCS, a control algorithm acts as an operating tool in order to minimize overflows. The results of real time control applications are shown in Figure 3 for each of the detention facilities at Ense-Bremen.

Digital Mapping Systems

Increased restrictions on pollution due to storms (CSO events) are being imposed at a

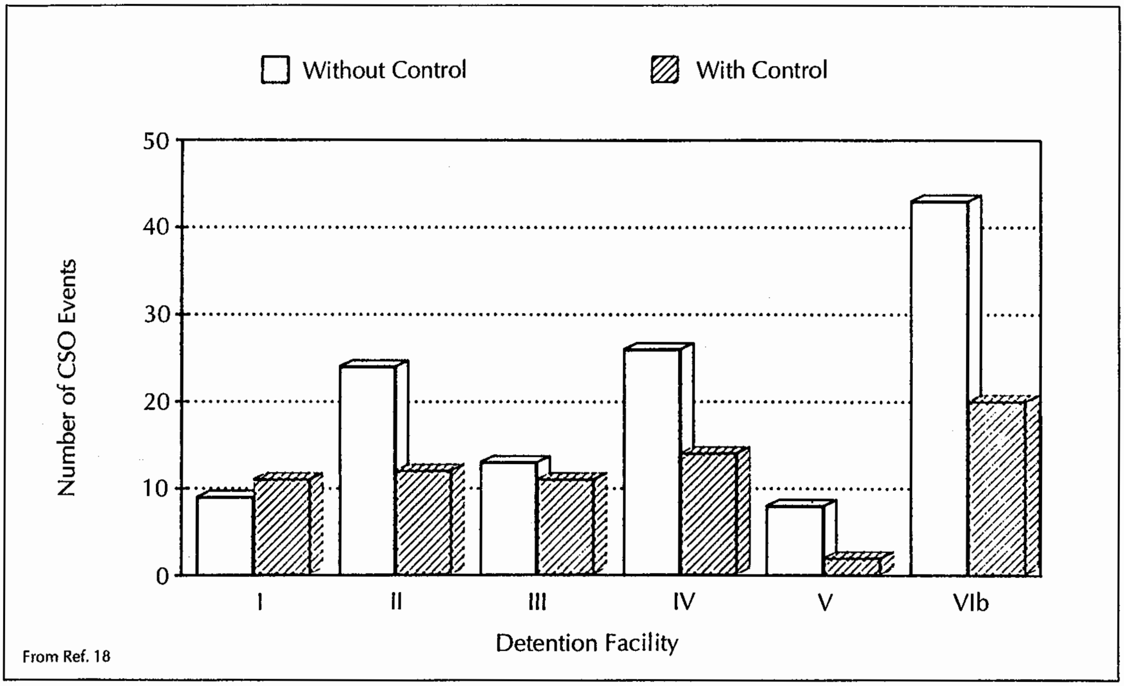

FIGURE 3. A graph showing the changes in the number of annual CSO events for each detention facility at Ense-Bremen.

time when digital mapping systems are coming into their own. Digital mapping systems are one of the most useful new technologies that have been developed for application in an UDS.

The heart of a digital mapping system is a spatial database that permits sewer utilities to control their capital resources (including collection systems and wastewater treatment plants).[19] The computer mapping system is used to translate the large database that covers the sewer collection system into a very effective tool for system operation and maintenance.

Some UDS authorities have utilized one type of database for these systems: the geographic information system used primarily for planning. Using large-scale-base maps, the sewer operator is able to overview the system.

Other authorities have favored a cadastral-based digital mapping system that utilizes plane coordinates to furnish details for site maps. Data for this type of system are taken from manhole record cards and from detailed as-built construction plans and street layouts. All of these maps are linked to permit zoom-in or zoom-out features.[20-22]

Tokyo has undertaken implementing a digital mapping system for its UDS that includes 400,000 manholes, 1,600,000 inlets and 8,153 miles of pipe.[7] The digital mapping system for greater Tokyo was put on-line in 1986 and will be 90 percent complete this year. Figure 4 shows a sample of the mapping system's digitized sewer system plot. The mapping system uses a mini-computer as host and the estimated cost for entering all the system data is $30 million.

ASCE Technical Visitations

The ASCE 1991 Technical Visitation program included meetings with and presentations by engineers, site visits, and meetings with consultants and university representatives. The visiting group of American civil engineers included ASCE President James E. "Tom" Sawyer, ASCE Executive Director Edward Pfrang, and practicing consulting engineers and civil engineering faculty from U.S. universities and colleges. The portion of the itinerary reported here is presented in Table 3.

Subway Site Under Construction in Vienna

The Vienna U-Bahn (underground rail) system

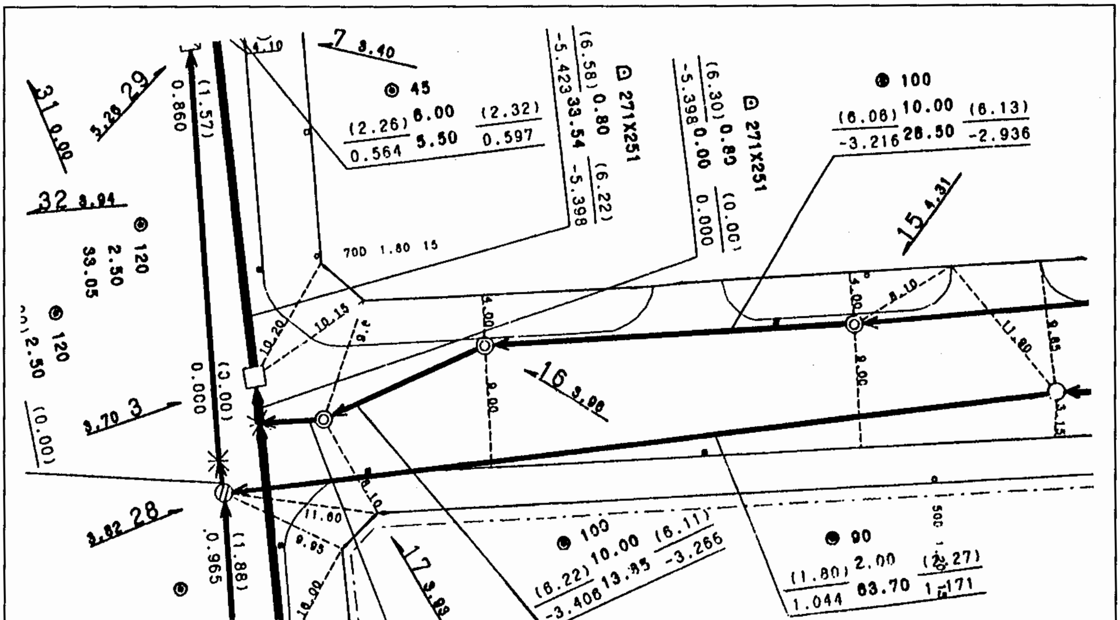

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FIGURE 4. A digitized map from Tokyo's sewerage and mapping information system.

was designed to operate in conjunction with existing surface trolleys and buses (see Figure 5). Surface trolleys began operation in Vienna in 1898, one year after the enfranchisement by the Massachusetts Legislature of the newly organized Boston Elevated Railway Company.[23] Underground transit systems are constructed when above-ground systems are considered to be impractical. The development of Boston's subway system provides an example of the technical, financial and political issues that affect most modern mass transit systems. Alphaeus Thomas Mason summarized the beginning of Boston's subways:

> "Prior to 1893 congestion in the business center had already become intolerable.... [It] could be entered through only two main arteries — Tremont and Washington streets. High real estate values in this area made it financially impracticable to widen streets, open new thoroughfares, or build an elevated. The city itself therefore constructed a subway under Tremont Street. Gathering up traffic from trolley lines extending miles into the suburbs, the subway provided the one route for surface and elevated cars through the heart of the city. With the subway in municipal hands and leased to the Elevated on short and reasonable terms, the city still had command and could thereby circumvent, perhaps, the extraordinary charter privileges granted in 1897."[23]

Construction for Vienna's subway began in 1974. Helmut Zilk, mayor of Vienna, has stated:

TABLE 3
Visitation Schedule

Date	Description of Activities
6/11/91	Subway Site Under Construction, Vienna, Austria
6/11/91	Meetings at the Slovak Technical University, Bratislava, Czechoslovakia
6/14/91	Meetings With the Hungarian Engineering Societies, Budapest, Hungary
6/14/91	Automobile Manufacturing Plant Under Construction, Esztergom, Hungary

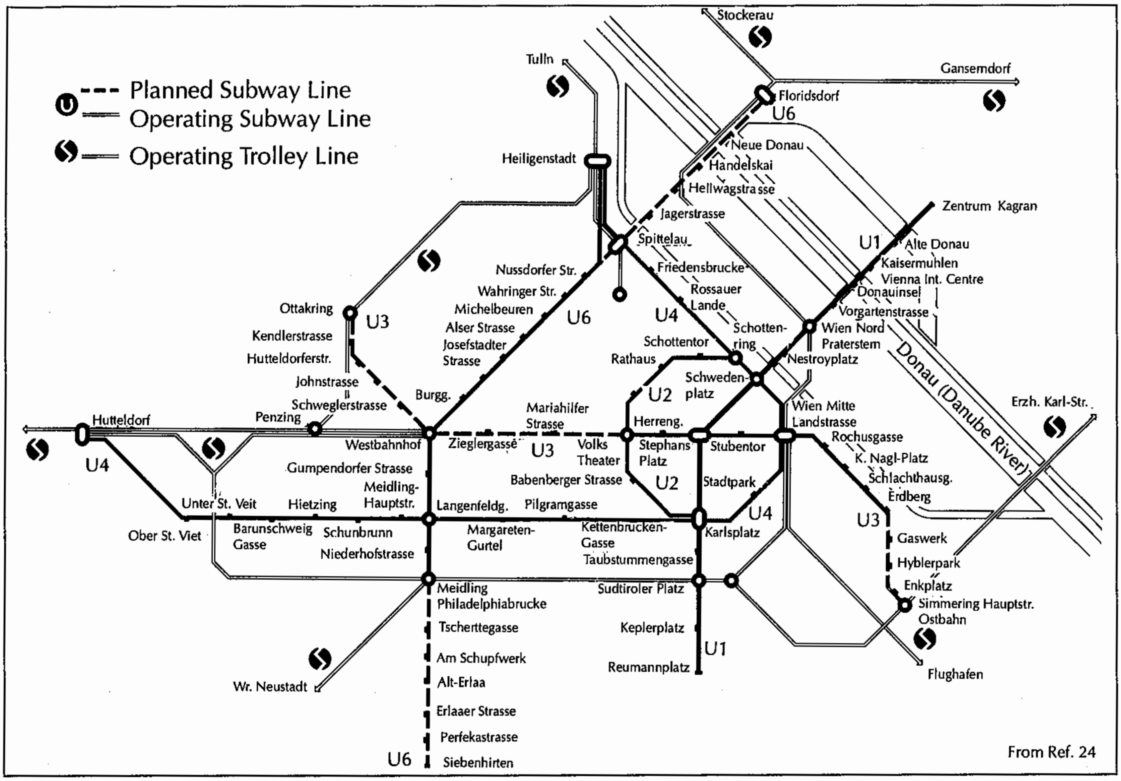

FIGURE 5. A system map of the Vienna U-Bahn subway.

"The opening of the first section of the underground railway in Vienna in the mid-1970s marked the beginning of an era with countless advantages, without which everyday life in the federal capital can no longer be imagined. Not only is the U-Bahn an extremely quick, efficient, safe and ecologically beneficial means of transport; it is no doubt the most attractive alternative and most efficacious competition for private car traffic which poses great problems to big cities worldwide."[24]

The construction of the U-Bahn's U3-U6 terminal was the topic of the informational meeting and an escorted construction site visit, including the presentation of an overview of the U3 segment of the subway system by Walter J. Hinkel, chief engineer for U-Bahn-Bau. The U3-U6 station is being constructed below the Europlatz, a plaza in front of the existing railroad station and below Gerstnerstrasse, a major city street.

The problems of maintaining local traffic and business activities are severe. Over 90,000 vehicles use the roadways above the station each day. Eight trolley lines traverse the surface area above the station with 144 trolleys in operation. And, over 4,500 pedestrians, mostly people changing trolleys, throng the square.[24]

When completed, the U3-U6 station will be one of the largest interchange stations in Austria. It will have a capacity of 24,000 users per day, including 10,000 people during peak evening rush hours. The platform area of the station will encompass 4,750 square meters (1.2 acres).

The U3-U6 station is one of seventeen stations that are currently under construction for the 13.5-kilometer (9.2-mile) U3 subway line. The line will take ten years to construct, and by the end of the 1990s it will be the largest construction project ever undertaken in Vienna. Trains will operate every three minutes and will utilize 87 "Silver Arrow" double power cars.

Subsurface Conditions. The U3 underground railway runs from the Danube River valley in

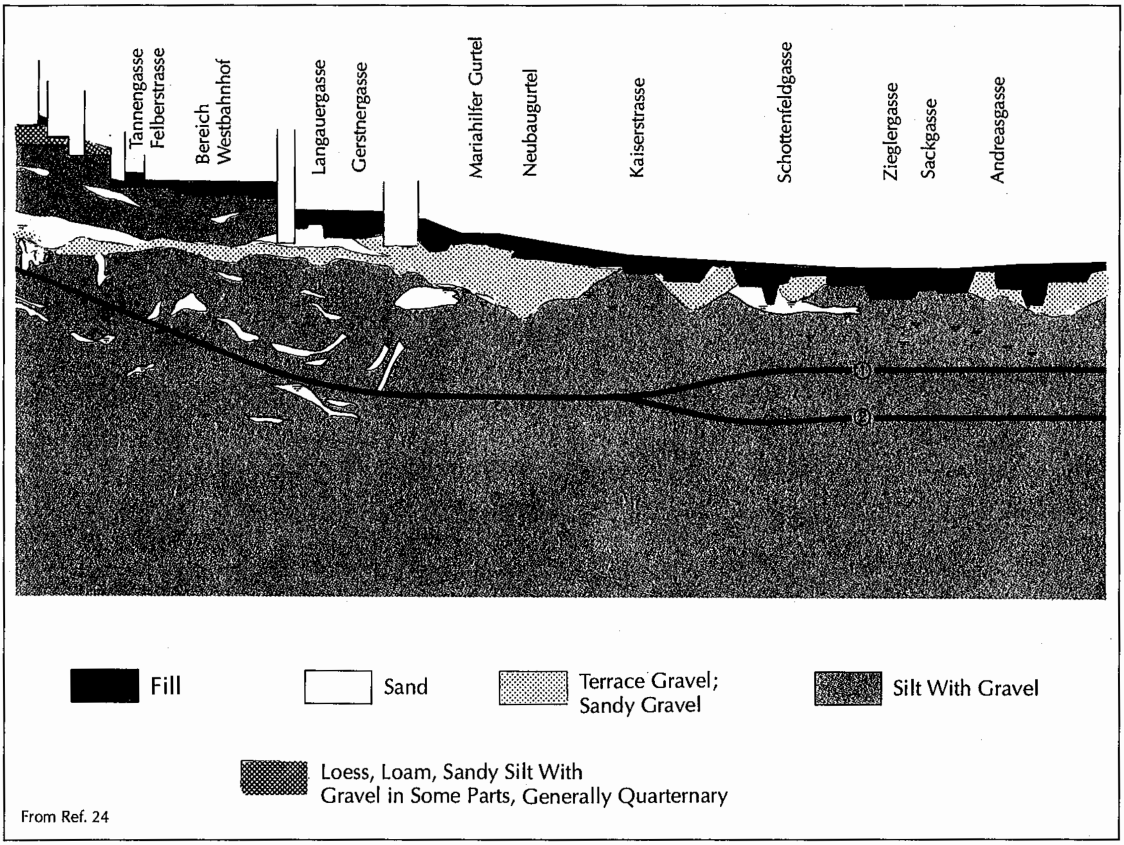

FIGURE 6. Simplified subsurface conditions in the vicinity of the U3-U6 station in Vienna.

the east to the Ottakring on a high terrace to the west. The soil conditions range from a mixture of sand and gravel river deposits to silt and clay deposits at higher elevations to the west. Although bedrock was not encountered, fault lines in the alluvial soil reflect shifting bedrock below. Most of the U-Bahn is constructed below the natural water table and extensive dewatering and groundwater equalization methods were required. A subsurface cross-section in the vicinity of the U3-U6 station is shown in Figure 6.

Construction Techniques. Two principal methods were employed to construct the U3 subway line: open excavation using diaphragm walls, and the New Austrian Tunneling Method (NATM). NATM consists of:

1. The ground is dug out meter by meter from a startup shaft with the aid of conventional excavating equipment or boring machines.
2. The ground is secured in cross sections by steel arches, structural steel grills and shotcrete.
3. Excavation and reinforcement are done in three installments — the upper third first, then the middle and finally the base — until the entire elliptical tunnel ring is completed.
4. A 40-centimeter (16-inch) thick inner concrete shell is then poured in place using pre-cut and pre-bent reinforcing bars and reusable steel forms.

NATM was used for a 110-meter (361-foot) stretch of the subway cross section. NATM had been used already in the U3 project for 5,783 meters (3.6 miles) of single-track tubes, 402 meters (1,319 feet) of station tubes and 358 meters (1,175 feet) of cuts and connecting galleries.

At the U3-U6 station, a triple tube is being built that requires six-phase construction. All of the phases utilize NATM. This type of tunneling was required because the station lies directly under the office building that houses the

Austrian Federal Railway office and under a small city square that is a nature preserve. A modified soil fracturing technique was employed under the railway office building to limit settlements. This technique involved setting three injection shafts close to the building and then drilling horizontal injection shafts below the building but above the proposed subway tunnel. A series of settlement monitoring devices, including 9,000 meters (5.6 miles) of boreholes supplied information on settlement. As construction proceeded, cement mixture injections were made to reduce settlement. Fifty-four percent of the expected settlements were prevented. Figure 7 presents views of the settlement reduction plan.

Meetings at the Slovak Technical University

The Czechoslovak Scientific and Technical Society hosted a meeting in Bratislava. Several papers were presented at this meeting on engineering projects in Czechoslovakia that are currently underway.

The Gabcikovo-Nagymaros Project. The Gabcikovo-Nagymaros Project (GNP) is a water resource project on the Danube River that was planned to provide hydroelectric energy, flood protection and navigation improvements. The project is only half completed and may never be fully completed as initially planned due to environmental opposition, political changes and financial problems.

The GNP involves two major dams on a portion of the Danube River lying between Bratislava, Czechoslovakia, upstream and Budapest, Hungary, downstream (see Figure 8). The upstream dam is the Dunakiliti Weir, located downstream of Bratislava. The other dam is at Nagymaros, Hungary, just upstream of the Danube Bend and Budapest. Associated with the Dunakiliti Weir is a power/navigation canal that runs 17 kilometers (10.6 miles) downstream to a power station at Gabcikovo, Czechoslovakia. The GNP was designed to deliver a capacity of 878 megawatts of electric power at daily peak periods and an estimated 3.7 billion kilowatt-hours of electric energy.

The project was the result of a bilateral treaty that was signed in 1977 between the former Communist governments in Czechoslovakia and Hungary. Work in design and construction proceeded until 1983 when both countries agreed to a four-year construction delay. During the 1980s, an environmental movement in the Communist Hungarian state, along with severe economic constraints, caused Hungary to withdraw its support and abandon the project. An impasse currently exists between the two countries regarding the status of the project. Table 4 presents an approximate breakdown of the monies spent to date on the project.[25]

The project would impact navigation not only in Hungary and Czechoslovakia, but on the entire Danube River. Another major water resource project, the Rhine-Main-Danube Canal, was completed in September 1992. This major canal project links the Baltic Sea with the Mediterranean. The Danube River Commission (that comprises the eight riparian owners along the Danube) is concerned about the maintenance of the existing navigational channel if the Dunakiliti-Gabcikovo power canal is not put into service.

Some European civil engineers feel that the impact of the Rhine-Main-Danube Canal may not be as significant as expected. Transportation officials believe that new roadways with efficient truck capabilities and new rail transport facilities could easily be more efficient than the existing barge cargo transport system. For example, a new automobile factory in Hungary, located near the Danube River will not have access to the river.

Czechoslovakia's Transportation System. Czechoslovakia's location at the geographic center of Europe makes it an important link between Western Europe and the Ukraine.[26] Rail, road and air transport systems in Czechoslovakia need to be linked into a combined transport system. However, many hurdles must be overcome.

In 1989, the Czechoslovakian railway system carried about 2.3 billion passenger miles and approximately 340 million tons of goods. Railway use is promoted in that country because it provides energy savings, impacts the environment minimally and offers an excellent safety record. Two recent international agreements will help shape the future of Czechoslovakia's railways. The first agreement

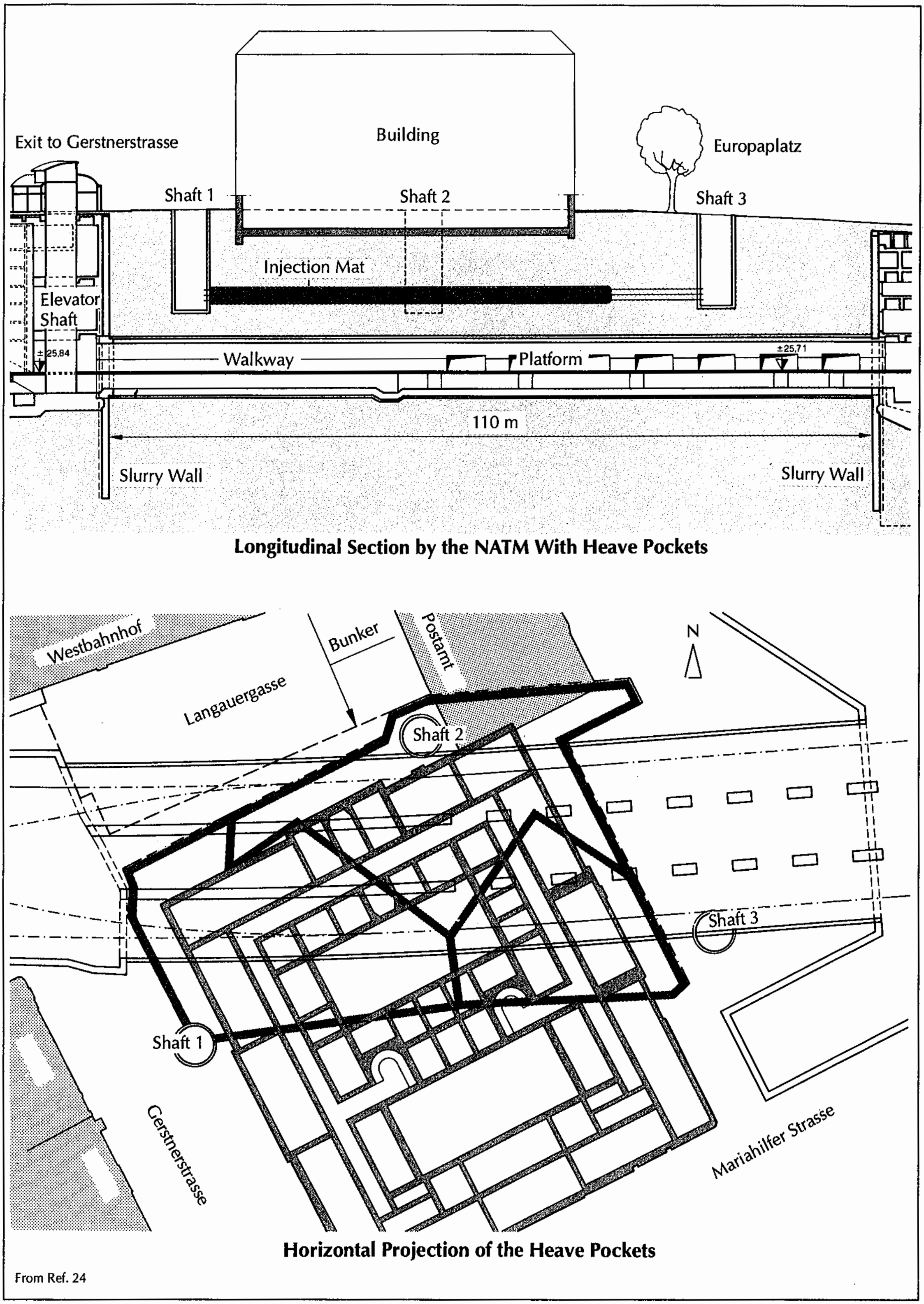

FIGURE 7. Profile and plan views of the modified soil fracturing technique.

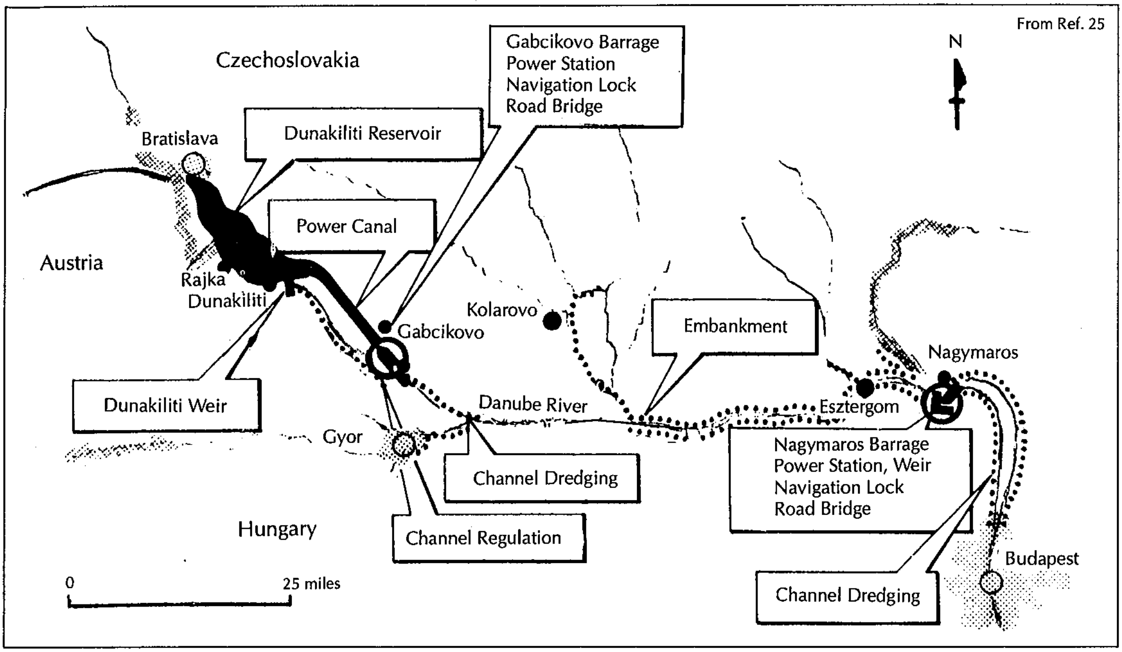

FIGURE 8. The general layout of the Gabcikovo-Nagymaros Project.

concerns incorporation into the international railway network. Reconstructed tracks will be designed for 160 kilometers per hour [kmph] (100 miles per hour [mph]) and new tracks will be designed for 250 kmph (156 mph). The second agreement defines Czechoslovakia's part in the Trans-European North-South Railway Project sponsored by the European Community. Upgrades are planned in a three-stage construction plan that is scheduled for completion in 2020. The estimated cost is $6.9 billion.

Czechoslovakia's motorways, as shown in Figure 9, are equivalent to our interstate road system. Since 1967, about 500 kilometers (311 miles) of highways have been built. The total designed length of their highway system is planned to be 1,835 kilometers (1,140 miles). The main axis would link Germany and the Ukraine. The roads are designed for 80 kmph (50 mph) in mountainous regions and 120 kmph (75 mph) in flat valley regions.

Some of the problems in completing the highway system are:[27]

- Inadequate financing
- Ineffective system for highway management
- Inexperience in applying thin resurfacing layers and pavement rehabilitation
- No environmental controls on road construction
- Lack of auto emissions standards.

In 1990, seven airports were opened in the country to international travel. The country's principal airport at Prague handled 1.95 million passengers in 1990. The second major airport in Bratislava handled 0.5 million passengers in 1990. Both of these airports are scheduled for expansion with new runways and larger facilities. One international airport

TABLE 4
Estimated Costs & Funds Spent on the Gabcikovo-Nagymaros Project as of June 1991[24]

Country	Total Estimated Costs (millions)	Money Spent to Date (millions)	Percent of Total Cost
Czechoslovakia	$630	$533	84
Hungary	$713	$291	41

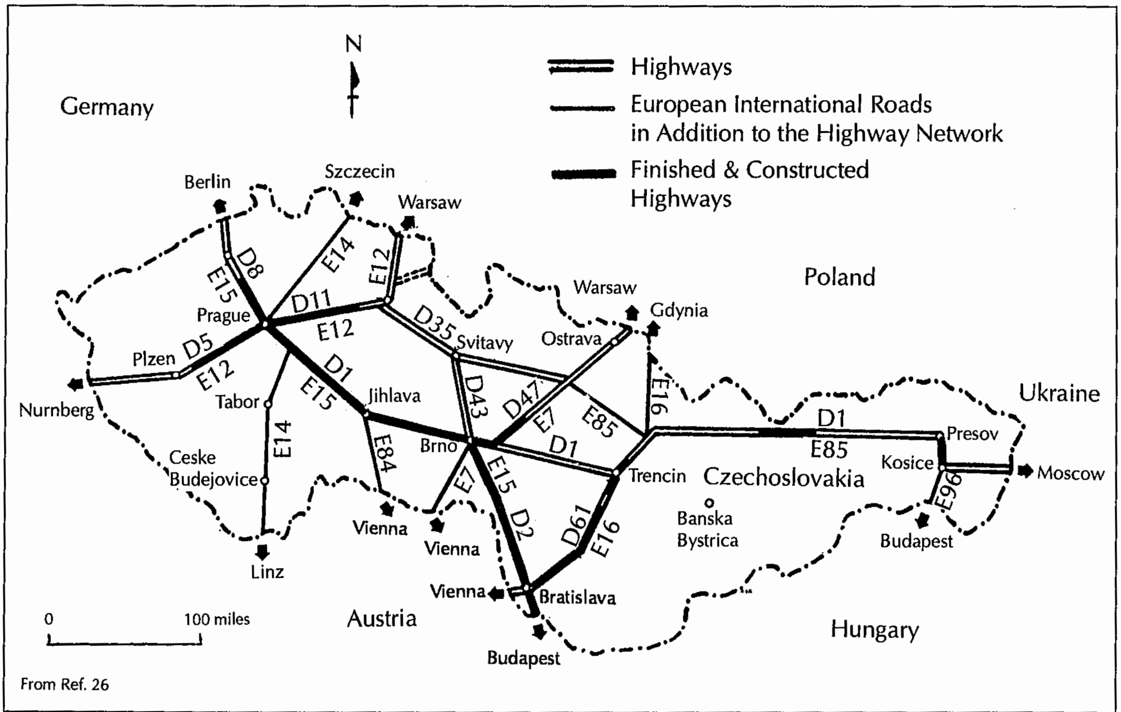

FIGURE 9. The layout of Czechoslovakia's highway network.

is presently closed for runway repairs and several proposed national airports currently have short grass runways.

Reducing Energy Consumption in Existing Residential Buildings. In 1980, there were 4,996,329 people living in the Slovak Republic (the southern half of Czechoslovakia). Housing consisted of 1,413,932 living units.[28] Fifty-eight percent of these living units were located in single-family dwellings and 40 percent were located in residential buildings. Most of the units in residential buildings were built from 1960 to 1980. These buildings are large, high-rise, concrete block structures. The average size of a living unit is 82 cubic meters (2,896 cubic feet). Forty-eight percent of the units are heated with solid fuel (coal) that causes severe air pollution in urban areas. Research is underway to determine ways of insulating these units to reduce energy consumption.

Meetings With the Hungarian Engineering Societies in Budapest

The civil engineering professional structure in Hungary is broken down by discipline. The related societies include:

- The Scientific Society for Building
- The Scientific Society for Transport
- The Hungarian Hydrological Society
- The Hungarian Society of Surveying and Remote Sensing

The Scientific Society for Building is headquartered in Budapest and includes structural and construction engineering disciplines. The society organizes meetings and lectures for its 5,300 members. The society also provides a forum for publications relating to building/structural engineering.[29]

The Scientific Society for Transport has 9,000 members and is divided into five divisions: railway, waterway, city transport, building traffic (local) and universal traffic (intercity). This society organizes technical meetings and courses related to transportation engineering. It also supports a high school and college outreach effort.[30]

Founded in 1866, the Hungarian Hydrological Society deals with all aspects of the water cycle. The society's 5,000 members include engineers, chemists, biologists and other scientists. It publishes a hydrological journal and is

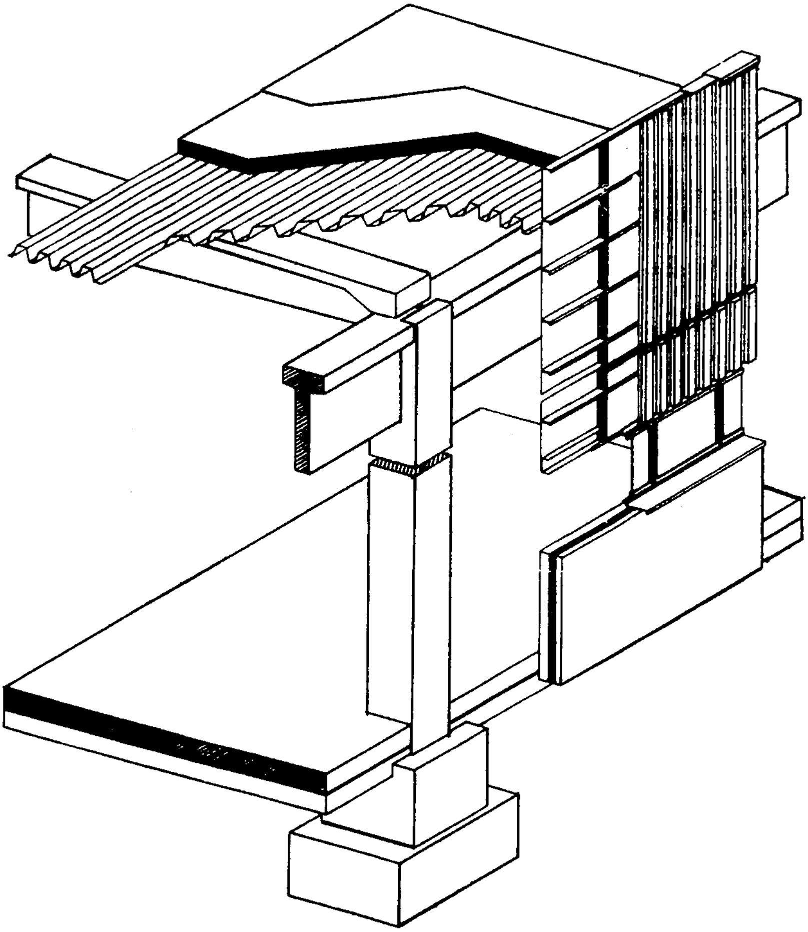

FIGURE 10. Isometric view of the main building envelope of the automobile factory.

a member of the International Water Supply Federation, the Limnology Society and the International Society of Agricultural Engineers.[31]

The Hungarian Society of Surveying and Remote Sensing, founded in April 1956, has 2,000 members. It meets in a general assembly every two years. The society maintains a bibliography of mapping and related topics dating from 1498. The Surveying Medal of Honor is named the "Lazardal Medal" after the maker of the map of Hungary drawn in 1527. The society has many joint meetings with the German and Austrian surveying groups and it is a member of the International Cartographic Association.[32]

The education of civil engineers in Hungary occurs in varying stages of complexity. Civil technicians are trained in technical schools that provide four years of high school education and require a comprehensive examination for certification. Each high school belongs to a university program. The Budapest Technical University is the main education center for civil engineers in Hungary. Other universities specialize in related topics, such as at the university located at Sopron that provides degrees in forestry and mining.

Site Visit to an Automobile Manufacturing Facility in Esztergom, Hungary

This new automobile assembly plant being constructed by Hungarian contractors will provide 32,000 square meters (7.9 acres) of working space. The plant will include a stamping shop, welding shop, assembly shop and paint shop. The main building is made almost entirely of pre-cast, reinforced concrete. The pillar construction is based on a 12- by 18-meter (40- by 60-foot) bay.[33] The building is covered with a lightweight steel roof deck and sides of trapezoidal sheets. The exterior walls of the assembly shop are constructed of brick. An isometric view of the main building envelope is presented in Figure 10.

A former Soviet Army base, the site is a flat one, located on a terraced flood plain above the Danube Bend area near Esztergom. No water terminal is planned for this plant on the Danube River. Railroads will serve the site. The subsurface consists of river deposits of sandy silts with some gravel and provides excellent foundation conditions.

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REFERENCES

1. Desbordes, M., Durepaire, P., Gilly, J.C., Mason, J.M., & Maurin, Y., "Inondations sur Nimes et sa region," ed. C. Lacour, Nimes, 1989.

2. Desbordes, M., "Characteristics of Heavy Rainfalls in the European Part of Mediterranean Basin," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 3–12.

3. Vukmirovic, V., & Petrovic, J., "Statistical Analysis of Storms — A Basis for Urban Runoff Modeling," *Wat. Sci. Tech.*, Vol. 16, 1984, pp. 86–92.

4. Vignoles, M., Dastugue, S., & Herremans, L., "Rainwater Quality in Toulouse: Influence of Pollution from the Atmosphere," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 29–44.

5. Delrieu, G., Creutin, J.-D., & Andrieu, H., "Weather Radar and Urban Hydrology in the Context of Mountainous Mediterranean Regions," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 53–61.

6. Einfalt, T., Denoeux, T., & Jacquet, G., "A Radar Rainfall Forecasting Method Designed for Hydrological Purposes," *Journal of Hydrology*, 1990, Vol. 114, pp. 229–244.

7. Fujita, S., "Rainfall-Runoff Analysis Using 20,480 Rain Gauges," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 71–77.

8. Grottker, M., & Schilling, W., "Planning, Implementation and Operation of Centralized Data Acquisition Systems — The Fehraldorf Case," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 81–89.

9. Guillon, A., "Evaluation of the Performance of the Ultrasonic Devices Used for the Measurement of Velocity," RESEAU Association, Ile-de-France, July 1990.

10. Ball, J.E., "Temporal Pattern Influences on Catchment Response," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 135–142.

11. Afshar, A., & Shokooh, J.R., "Non-linear Optimization Model for Optimum Operating Strategy," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 143–152.

12. Radojkevic, M., & Maksimovic, "Development, Testing and Application of Belgrade Urban Drainage Model," Proceedings of the 3rd ICUSD, Göteborg, Sweden, Vol. 4, 1983.

13. Lindberg, S., Nielson, J.B., & Carr, R.S., "An Integrated PC-Modeling System for Hydraulic Analysis

and Drainage Systems," Watercomp 89, Proceedings of the 1st Australasian Conference on Technical Computing in the Water Industry, Melbourne, Australia, May/June 1989.

14. Sheng, Y.P., "Modeling of Three-Dimensional Coastal Currents and Sediment Dispersion, Vol. 1, Model Development and Application," Technical Report CERC-83-2, Coastal Engineering Research Center, Vicksburg, Mississippi, 1983.

15. Harremoes, P., "Real Time Control — In Context," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 453–463.

16. Field, R., "Storm and Combined Sewer Overflow: An Overview of EPA's Research Program," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 291–295.

17. Schilling, W., "Introduction to Simulation and Real Time Control," WPCF Pre-Conference Workshop on Simulation and Real-Time Control of Urban Drainage and Wastewater Systems, Washington, DC, 1990.

18. Weyland, M., & Dohmann, M., "Real Time Control Within a Combined Sewer System — Analysis and Assessment of Practical Results," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 469–479.

19. Westerling, D.L., "Possibilities for Real Time Control of Combined Sewer Systems in the Northeast United States," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 465–468.

20. Granjean, I., & Zech, Y., "Rainfall-Runoff Modeling of Partly Urbanized Watersheds, Use of Digital Terrain Models," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 365–372.

21. Delaplace, D.M., & Price, R.K., "Urban Drainage Models Linked to CAD and GIS: The UK Experience," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 373–387.

22. Parrish, R., "The Use of Computers for Sewer Records and Drainage Area Planning," Proceedings of UDT 91, Dubrovnik, Yugoslavia, 1991, pp. 389–397.

23. Mason, A.T., *Brandeis, A Free Man's Life,* Viking Press, 1946, p. 107 ff.

24. Hinkel, W.J., "A Documentation on the Construction and Operation of the U3 as of April 6th, 1991," MA 38–U-Bahn-Bau, Vienna, 1991.

25. Liska, M., "Gabcikovo-Nagymaros Project: Basic Information About Its Actual Size and Perspectives," Hydroconsult Bratislava, June 1991.

26. Ciller, V., Corej, J., & Sokolik, A., "Czecho-Slovak Federative Republic in Europe's Transport System," University of Transport and Communications, Zilina, Czechoslovakia, June 1991.

27. Dula, I., "The Transportation and the Environment: Bratislava as an Example," Traffic Institute of Bratislava, June 1991.

28. Sternova, Z., "Reduction of Energy Consumption in Existing Residential Buildings Stock of Settlements Construction," Research and Development Institute for High Buildings, Bratislava, June 1991.

29. Markus, M., President of the Scientific Society for Building, General Manager of State Building Trade Company No. 31, personal presentation, Budapest, June 14, 1991.

30. Bakonyi, F.P., Scientific Society for Transport, Chief Engineer of Motorway Construction Company, personal presentation, Budapest, June 14, 1991.

31. Raum, L., Hungarian Hydrological Society, General Engineer for Ungarische Hydrologische Gesellschaft, personal presentation, Budapest, June 14, 1991.

32. Domokos, G., Hungarian Society for Surveying and Remote Sensing, Managing Director Hungarian Company for Surveying and Mapping, personal presentation, Budapest, June 14, 1991.

33. Markus, M., "Magyar Suzuki Co., Esztergom Automobile Factory," informational bulletin from Building Trade Company No. 31, Budapest, undated.